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EMISSIONS COMPARISON OF ALTERNATIVE FUELS IN AN ADVANCED AUTOMOTIVE DIESEL ENGINE

INTERIM REPORT
TFLRF No. 338

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For

Department of Energy
Energy Efficiency And Renewable Energy
Office of Transportation Technologies
Office of Advanced Automotive Technologies
Washington, D.C.

Under Contract to
U.S. Army TARDEC
Petroleum and Water Business Area
Warren, MI

Contract No. DAAK70-92-C-0059

September 1998

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REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE (Leave blank)	2. REPORT DATE September 1998	3. REPORT TYPE AND DATES COVERED Interim, October 1997 to April 1998

4. TITLE AND SUBTITLE Emissions Comparison of Alternative Fuels in an Advanced Automotive Diesel Engine	5. FUNDING NUMBERS DAAK70-92-C-0059 WD 69
6. AUTHOR(S) Sirman, M.B., Owens, E. C., and Whitney, K. A.	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army TARDEC Fuels and Lubricants Research Facility (SwRI) Southwest Research Institute P.O. Drawer 28510 San Antonio, Texas 78228-0510	8. PERFORMING ORGANIZATION REPORT NUMBER IR 338
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army TACOM U.S. Army TARDEC Petroleum and Water Business Area Warren, Michigan 48397-5000	10. SPONSORING/ MONITORING AGENCY REPORT NUMBER
11.SUPPLEMENTARY NOTES	
12a. DISTRIBUTION/AVAILABILITY	12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

Exhaust emissions mappings were conducted for six alternative diesel fuels in a Daimler-Benz (DB) OM611 diesel engine. The OM611 engine is a 2.2L, direct-injection diesel with a Bosch, high-pressure, common-rail, fuel-injection system. The engine design closely matches the specifications of the Partnership for a New Generation Vehicle (PNGV) target compression- ignition engine. Triplicate 13-mode, steady-state test sequences were performed for each fuel, with a 2-D control fuel serving as the baseline. No adjustments were made to the engine to compensate for any performance differences resulting from fuel property variations.

14. SUBJECT TERMS Light-duty Diesel, Emissions, Gaseous Emissions, Particulate Emissions, DMM, Methylal, Alternative Fuels, Diesel Fuels, Synthetic diesel, Biodiesel	15. NUMBER OF PAGES 35
	16. PRICE CODE

17.SECURITY CLASSIFICATION OF REPORT	8. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT

EXECUTIVE SUMMARY

Background and Objectives –The Partnership for a New Generation Vehicle (PNGV) has identified the compression-ignition, direct-injection (CIDI) diesel engine as a promising technology in meeting the PNGV goal of an 80-mpg, production-prototype, mid-sized sedan by 2004. Challenges remain in reducing emissions levels of the CIDI engine to meet future emissions standards. Techniques under consideration for emissions control include improved combustion processes, after-treatment devices, and alternative fuels. The objective of this program was to perform an initial screening of several reformulated and alternative diesel fuels to obtain information on their potential for emissions reduction in a CIDI engine.

Technical Approach –The Department of Energy initiated this testing to determine the emissions impact from various fuel blends in a CIDI engine. The emissions testing was performed utilizing a Daimler-Benz model OM 611 diesel engine. This engine is a 2.2L, direct-injection diesel equipped with a high-pressure, common-rail injection system. The OM 611 also has variable EGR, is turbocharged with intercooling, and has variable intake swirl capability. No adjustments were made to the engine operating parameters to account for variations in the fuel properties.

Seven fuels were included in the test program. A 2D EPA certification diesel served as the baseline for comparison of the remaining six fuels. The reformulated/alternative fuels included: "pseudo-California Certification fuel (CARB); Low-Sulfur Low-Aromatics diesel (LS); Neat Fischer-Tropsch synthetic diesel (FT100); Twenty-percent blend of biodiesel in fuel LS (B20); Twenty-percent blend of Fischer-Tropsch in fuel LS (FT20): Fifteen-percent blend of Methylal (DMM) in fuel LS (DMM15).

The test sequence consisted of 13 steady-state speed and load points. The 13 points are not related to the standard, EPA 13-mode test for heavy-duty engines. The test sequence was repeated three times for each fuel in a randomized test matrix. For each test mode, emissions of total particulate matter (PM), oxides of nitrogen (NOx), carbon monoxide (CO), total hydrocarbons (HC) and fuel consumption were measured. A particulate size distribution was determined for each fuel during one of the triplicate 13-mode tests. The data are engine-out emissions only, and the exhaust after-treatment system was disconnected.

Results –All six alternative fuels showed a reduction in PM emissions compared to 2D, with no statistically significant increases in NOx emissions. For an equally weighted average of the 13 test modes, the DMM 15 blend produced a 52-percent reduction in particulates when compared to the 2D baseline fuel. Fuel FT100 reduced PM emissions by 37 percent, with B20 showing a 32-percent reduction. Several of the alternative fuels significantly reduced HC emissions at the low-speed, low-load operating modes. Average reduction in HC ranged from 24 to 50 percent of the 2D level. Carbon monoxide emissions were reduced across the entire operating range of the engine. For the 13-mode average, CO reductions ranged from 15 to 36 percent. The particulate size distribution measurements indicated no gross differences among the seven test fuels.

Conclusions and Recommendations –This test program has demonstrated that emissions levels can be reduced through the use of reformulated and alternative fuels in a CIDI diesel engine. Particulate matter emissions were reduced with no significant increase in emissions of NOx. The DMM15 blend showed the largest reduction in PM (52 percent) followed by the FT100 fuel (37 percent) and the B20 blend (32 percent). Because of the volatility of DMM, the DMM15 blend required changes to the fuel system to prevent the DMM from boiling out of solution. This may cause problems if this fuel is to be used on a wide-scale basis. The Fischer-Tropsch fuel, however, was substituted in the engine with no alterations and also produced a good reduction in particulate emissions levels.

Based on the results of this test program, it is clear that additional work should be conducted in the area of alternative fuels. These results demonstrate that benefits can be achieved through the direct substitution of fuels in advanced diesel engines. Additional reductions in emissions may be possible if engine operating parameters such as injection timing and exhaust gas recirculation (EGR) levels can be adjusted for a specific fuel. Investigations of fuel system and materials compatibility will also be important along with the effects of alternative fuels on the performance of after-treatment devices.

FOREWARD/ACKNOWLEDGMENTS

This work was performed for the Department of Energy by the U.S. Army TARDEC Fuels and Lubricants Research Facility (TFLRF) located at Southwest Research Institute (SwRI), San Antonio, TX, in cooperation with the Department of Emissions Research (DER) at SwRI during the period October 1997 to April 1998 under Contract No. DAAK70-92-C-0059 for the U.S. Army TARDEC, Petroleum and Water Business Area. Mr. L. Villahermosa served as the TARDEC project monitor. This work was funded by the U.S. Department of Energy, Office of Transportation Technology (DOE/OTT). Mr. Jack Hale and Mr. John Garbak served as the DOE/OTT project technical monitors. DOE initiated this work in support of the Partnership of New Generation of Vehicles (PNGV).

The authors would like to acknowledge the assistance provided by Messrs. L. Schmid, W. Pütz and D. Naber of Daimler-Benz (DB), Stuttgart, Germany in supplying the engine and technical support for this testing program. Messrs. R. Frierson, R. De La Cruz, and W. Shackelford of DER performed the emissions testing under the supervision of Mr. D. Bohl. The authors would also like to acknowledge the assistance provided by Ms. W. Mills in report preparation.

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I. INTRODUCTION

Interest is growing in the performance and emissions benefits of advanced, compression-ignition, direct-injection (CIDI) engines. The Partnership for a New Generation of Vehicles (PNGV) is investigating the technical benefits of small, four-stroke, direct-injection (4SDI) compression-ignition engines. When coupled with alternative and/or reformulated fuels, the 4SDI engine has the potential to contribute significantly to the PNGV goal of developing an environmentally friendly car with triple the fuel efficiency of today's midsize cars [1]. New and pending emissions regulations around the world are also driving the interest in advanced engine technology and alternative fuels [2].

Many studies have demonstrated the emissions benefit of reformulated and alternative diesel fuels [3,4,5,6]. Variations in fuel properties have been shown to affect the emissions of light-duty vehicles. The most prominent effects result from variations in density, cetane number, sulfur content, and aromatics content.

For this program, exhaust emissions mappings were conducted for six reformulated and alternative diesel fuels utilizing a Daimler Benz (DB) OM 611 diesel engine. The OM 611 engine is a 2.2L, direct-injection diesel with a Bosch, high-pressure, common-rail, fuel-injection system. The engine design closely matches the specifications of the PNGV target compression-ignition engine. Triplicate steady-state test sequences were performed for each reformulated and alternative fuel, as well as a 2D certification-grade fuel that served as the baseline. Four of the test points were recommended by the PNGV, 4SDI technology team, with the remaining test points chosen to include the operating range of the engine. No adjustments were made to the engine to compensate for any performance differences resulting from fuel property variations.

The OM 611 engine is unique in that it utilizes a high-pressure, common-rail injection system. The common-rail system has been shown to have great potential to reduce exhaust emissions and noise, as well as improve engine design [7]. The OM 611 engine utilizes some of the most advanced design features, which will be incorporated into other commercially produced diesel engines in the near future. However, the reader should not

assume that the results of the subject series of tests are necessarily indicative of the best performance and lowest emissions to be achieved in diesel engines with the fuels selected for these tests.

Several fuels for which a substantial amount of operational experience already exists were selected for these tests. They were chosen based on a potential for low emissions through commercial production with an economically viable basis in the near future. These fuels will represent a baseline against which less-proven fuels can be compared. In the Phase I series of tests, no attempt was made to optimize the engine for the best possible results with each of the fuels. In a planned Phase II series of tests, it is anticipated that the engine will be specifically optimized for each of the test fuels. Phase I and II tests are structured to enable a comparison of candidate fuels and should not be construed as reflective of the average or best results to be expected in a scenario where these fuels are used on a commercial scale.

II. OBJECTIVE

The objective of this study is to compare the exhaust emissions of several promising alternative fuels in an advanced DI engine. This study is intended to serve as an initial screening of the fuels in order to investigate the level of benefit that can be achieved through alternative fuels. The emissions changes are compared through direct substitution of fuels in the engine. The engine was not modified to account for possible performance differences due to variations in the fuel properties.

The experimental approach to this work is described in Section III. This section includes a detailed analysis of the seven test fuels as well as a description of the test sequence and procedures. Section IV describes the engine performance and emissions results for each of the test fuels. Conclusions and recommendations are presented in Section V.

III. APPROACH

The test program was conducted for seven diesel fuels, with an EPA 2-D certification fuel serving as the baseline. The test sequence consisted of 13, steady-state speed/load points that covered the operating range of the engine.

A. Test Fuels

Exhaust emissions were measured for the seven fuels listed in Table 1. The EPA 2-D certification fuel (2D) is the baseline against which the emissions of the other six fuels are compared. The test fuels were chosen based on the expectation of emissions benefits from each fuel. Of the six alternative fuels, three are neat fuels and three are blends. The neat fuels include the following: a "pseudo" California diesel; a low-sulfur, low-aromatics diesel; and a Fischer-Tropsch synthetic fuel. The remaining test fuels are blends of interesting alternatives with the LS fuel. The blends include biodiesel, the Fischer-Tropsch synthetic diesel, and dimethoxymethane (DMM).

Table 1. Test Fuels

#	Fuel Code	Description
1	2D	EPA 2-D Certification Diesel
2	CARB	Pseudo-CARB Diesel
3	LS	Low-Sulfur Diesel
4	FT100	Synthetic (Fischer-Tropsch) Diesel
5	FT20	Blend; 20% Synthetic Diesel with 80% Low-Sulfur Diesel
6	B20	Blend; 20% Biodiesel with 80% Low-Sulfur Diesel
7	DMM15	Blend: 15% Dimethoxymethane (DMM) with 85% Low-Sulfur Diesel

Several fuel properties important to diesel engine emissions were measured for each fuel. The complete results of this analysis are listed in Table 2. Figures 1 and 2 show the distillation curves (by ASTM D86) for the neat fuels and blended fuels, respectively. The data in Table 2 and Figures 1 and 2 are discussed for each fuel in the following sections.

Table 2. Fuel Properties

Property	Units	ASTM	Baseline Fuel (2D)	California Diesel (CARB)	Low-Sulfur Diesel (LS)	Synthetic Diesel (FT100)	Biodiesel Blend (B20)	Synthetic Diesel Blend (FT20)	DMM Blend (DMM15)
Density @ 15C	g/mL	D4052	.849	0.831	0.811	0.781	0.826	0.806	0.817
Distillation		D2887							
IBP	°C		109	158	184	145	180	151	63
10%	°C		189	186	226	236	228	227	215
50%	°C		262	252	257	302	256	256	255
90%	°C		331	305	274	351	353	303	273
95%	°C		352	356	282	359	354	331	281
End Pt	°C		408	419	307	377	409	376	313
Distillation		D86							
IBP	°C		186	194	241	215	241	238	42
10%	°C		225	217	246	258	249	247	61
50%	°C		266	249	251	289	259	255	249
90%	°C		311	285	261	325	329	281	259
95%	°C		324	318	266	332	339	301	262
End Pt	°C		337	344	285	337	347	322	281
Cetane Number		D613	47	45	67	84	65	79	63
Aromatics	wt. %	D5186	32.5	8.9	1.2	0.2	0.6	0.6	0.7
Flash Point	°C	D93	76	69	101	98	104	100	< 9
Kin. Viscosity, 40 °C	cSt	D445	2.62	2.42	2.41	3.21	2.64	2.55	1.49
Carbon	mass %	D5291	85.3	86.0	85.6	84.8	83.7	85.3	80.8
Hydrogen	mass %	D5291	12.9	13.9	14.4	15.1	14.0	14.6	14.0
Oxygen	mass %	Difference	1.8	0.1	0.0	0.1	2.3	0.1	5.2
Sulfur	ppm	D2622	300	300	< 10	< 10	< 10	< 10	< 10
Nitrogen	µg/g	D4629	97.0	7.3	7.6	7.8	7.4	7.7	7.3
Net Heat of Comb	MJ/kg	D240	42.7	43.1	43.4	43.9	42.1	43.5	40.4

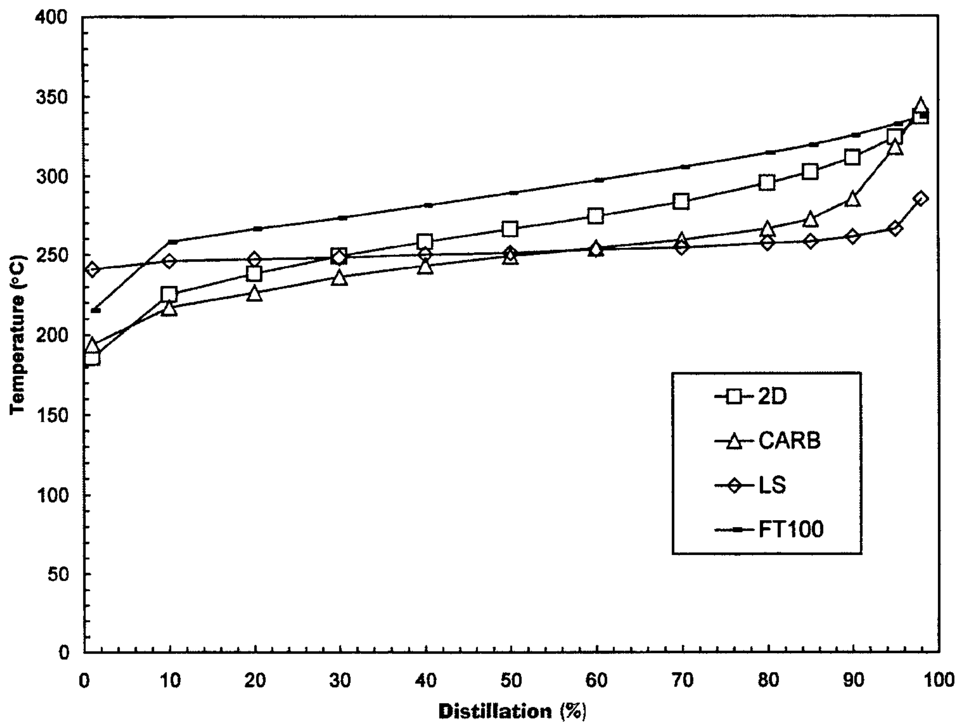

Figure 1. Distillation curves by ASTM Method D86: Neat Fuels

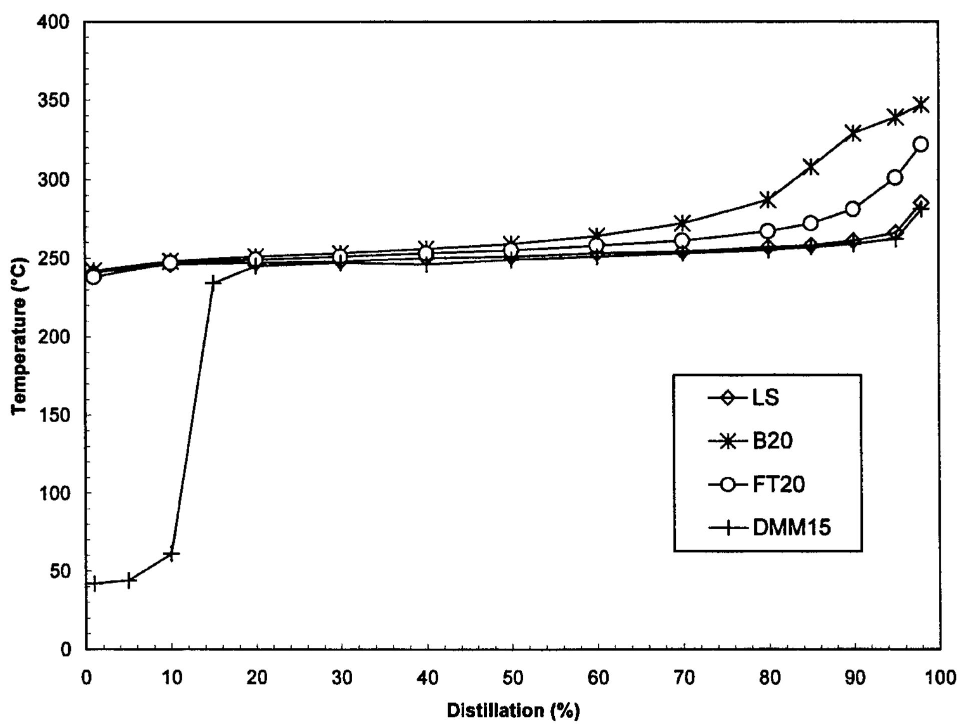

Figure 2. Distillation Curves by ASTM Method D86: Blended fuels and base LS fuel

1. EPA 2-D Certification Diesel (2D)

Fuel 2D meets the EPA specifications for a 2-D certification diesel fuel [8]. This fuel serves as the reference against which emissions from the six alternative fuels are compared. Fuel 2D is intended to represent a currently available U.S. diesel fuel [9]. As shown in Figure 1, the 2D fuel has a distillation curve typical of diesel fuels. This fuel has 32.5 percent aromatics by weight and 0.03 percent (weight) sulfur content. The cetane number of 47 is typical of a 2-D fuel available in the United States.

2. CARB Diesel (CARB)

The fuel labeled CARB in Table 1 is a "pseudo" California Reference fuel. This fuel closely matches the specifications for a CARB Certification fuel as described in the California Code of Regulations [10] and is used as such for the purposes of this research program. The CARB specifications require a sulfur level below 0.05 percent (mass) and aromatics under 10 percent (volume). The CARB fuel meets these specifications with 0.03 percent (mass) sulfur and 8.9 percent (weight) aromatics content. The initial and final boiling points of the CARB fuel match the 2D fuel, with the mid-range distillation occurring at slightly lower temperatures.

3. Low-Sulfur, Low-Aromatics Diesel (LS)

The third fuel is a low-sulfur, low-aromatics test fuel with properties comparable to a Swedish, Class I, urban diesel fuel [4]. Studies in Europe demonstrated a clear benefit in light-duty emissions with this type of reformulated fuel [3]. Fuel LS has less than 10 ppm sulfur and 1.2 percent (weight) aromatics content. As a result, this type of fuel typically has a higher cetane number than the 2D and CARB fuels. The LS fuel included in this test program has a cetane number of 67. Note in Figures 1 and 2 that the LS fuel has a very narrow distillation range with an initial boiling point at 241°C and a final point of 285°C.

4. Fischer-Tropsch, Synthetic Diesel (FT100)

Fuel FT100 is a synthetic diesel fuel produced from natural gas by the Shell Middle Distillate Synthesis (SMDS) process. Recent studies have shown that this type of

synthetic diesel fuel has great potential to reduce exhaust emissions when run as a neat fuel or as a blend with standard, crude-derived fuels [5]. As shown in Table 2, the FT100 fuel has a high cetane number of 84 with very little sulfur or aromatics content.

5. 20% Fischer-Tropsch Blend (FT20)

Fuel FT20 is a 20/80 blend of fuel FT100 with fuel LS. As expected, the addition of FT100 results in an increase in cetane number compared to the neat LS fuel. The FT20 blend has a higher Final Boiling Point than the LS base fuel (see Figure 2).

6. 20% Biodiesel Blend (B20)

Fuel B20 is a 20/80 blend of biodiesel with fuel LS. Biodiesel is defined by the National Biodiesel Board (NBB) as the "mono alkyl esters of long-chain, fatty acids derived from renewable lipid feedstocks, such as vegetable oils or animal fats, for use in compression ignition (diesel) engines" [11]. A provisional ASTM specification currently exists (Table 3), which indicates acceptable properties for pure (100%) biodiesel for use in diesel blends. The biodiesel in blend B20 was produced from a soybean feedstock and meets all of the ASTM provisional specifications.

Table 3. Provisional Biodiesel Specification for Pure (100%) Biodiesel [11]

Property	ASTM Method	Limits	Units
Flash Point	93	100.0 min	degrees C
Water & Sediment	1796	0.050 max	vol. %
Carbon Residue, 100% sample	4530*	0.050 max	wt. %
Sulfated Ash	874	0.020 max	wt. %
Kinematic Viscosity, 40°C	445	1.9 – 6.0	mm^2/sec
Sulfur	2622	0.05 max	wt. %
Cetane	613	40 min	
Cloud Point	2500	By Customer	degrees C
Copper Strip Corrosion	130	No. 3 max	
Acid Number	664	0.80 max	mg KOH/gm
Free Glycerin	GC**	0.020 max	wt %
Total Glycerin	GC**	0.240 max	wt %

*Or equivalent ASTM testing method.
**Austrian (Christina Planc) update of the United States Department of Agriculture test method.

The addition of biodiesel to the LS fuel had little effect on the cetane number. The density of B20 is slightly higher than LS, and the distillation curves in Figure 2 show that the temperatures at the 90- and 95-percent distillation points increased significantly. The biodiesel blend also contains a small amount of oxygen (2.3 percent by mass).

7. 15% DMM Blend (DMM15)

The final fuel is a 15/85 blend of dimethoxymethane (DMM or methylal) with fuel LS. This fuel is referred to as DMM15 in Table 1. DMM, $CH_3O\text{-}CH_2\text{-}OCH_3$, is readily synthesized from methanol, and is completely miscible in petroleum-based fuels. Preliminary studies indicated that DMM is effective in reducing smoke and particulate emissions when used as an additive in diesel fuels [12]. The addition of DMM drastically alters the initial boiling point and flash point of the LS fuel. Because pure DMM is very volatile, the 15/85 blend has an initial boiling point of 42°C and a flash point of less than 9°C. The blend has an oxygen content of 5.2 percent by weight and a slightly lower net heat of combustion than the other hydrocarbon-based test fuels.

The volatility of the DMM blend raised concern over the handling and storage of this fuel. In order to address these safety concerns, vapor-pressure measurements and ignition tests were conducted for a 15-percent DMM/Diesel blend. The ignition tests were performed in a sealed combustion vessel following the procedure outlined in Reference 13. The ignition test measured the blend's Upper Temperature Limit of Flammability (UTLF). Temperatures above the UTLF resulted in vapor concentrations too high to propagate a flame away from an ignition source. The UTLF was found to be 10°C (50°F), indicating that the 15/85 DMM blend does not present an explosion hazard in a fuel tank (or other closed container) at temperatures above 10°C (50°F) [14]. Based on the vapor pressure measurements shown in Figure 3 and the measured UTLF, the upper explosion limit (UEL) for the blend is equivalent to a vapor pressure of 2.2 psi, which corresponds to a concentration of 15 mole percent DMM in the vapor phase. The temperature for the lower explosion limit (LEL) was estimated to be -40°C (-40°F) by extrapolation of the vapor pressure data.

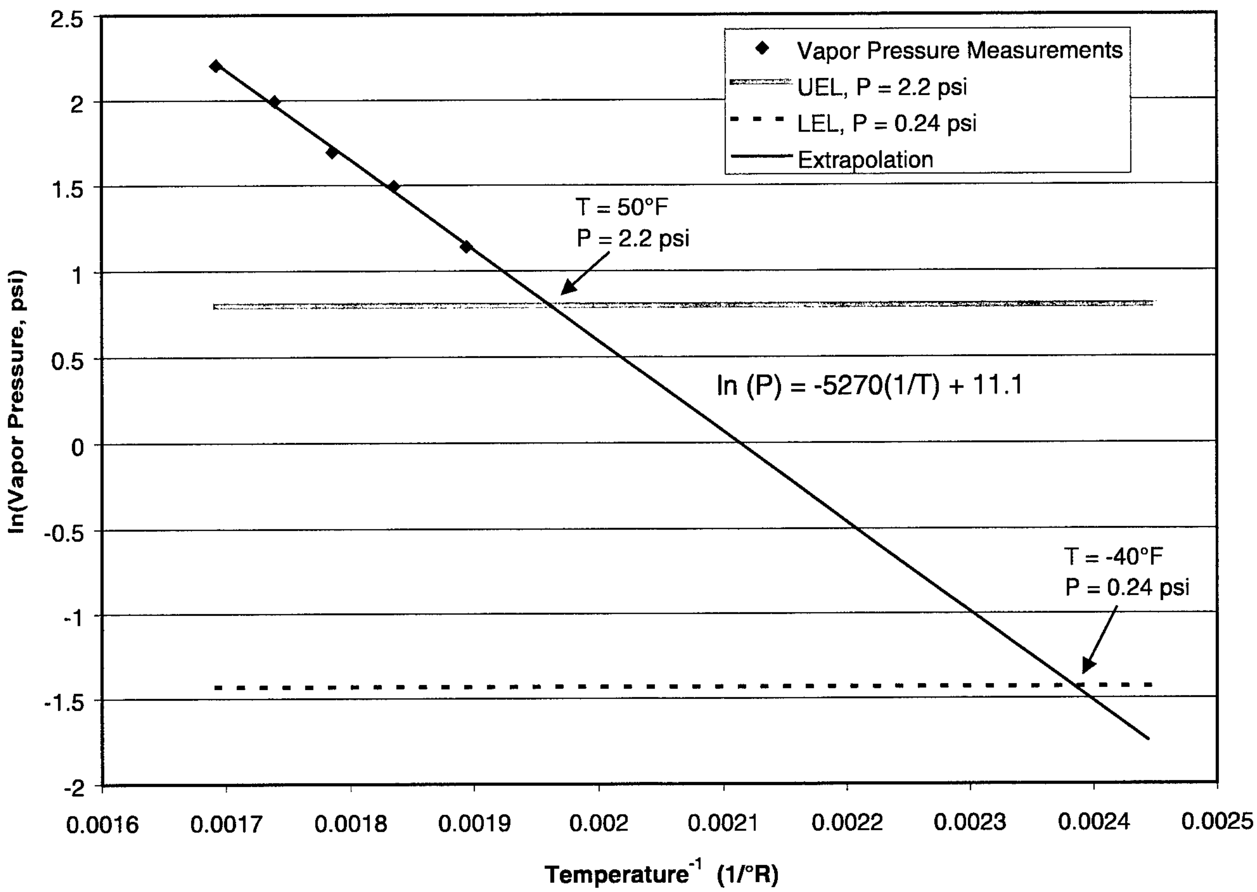

Figure 3. Upper and lower explosion limits for the DMM15 blend within a closed container

B. Test Engine

All emissions tests were conducted with the Daimler Benz, 2.2L, direct-injection diesel engine described in Table 4. This recently introduced, four-valve-per-cylinder engine is turbocharged and intercooled, and includes exhaust gas recirculation and intake port cut-off. No changes were made to the engine from the condition and settings provided by Daimler Benz. This engine is manufactured for sale in Europe, and as such, is calibrated to meet ECE15/EUDC emission standards. No oxidation catalysts were included in the exhaust system for these tests. The engine would normally run in a light-duty vehicle with two oxidation catalysts in the exhaust system that would reduce the HC and CO emissions from the vehicle [15]. No engine break-in was conducted as this engine was operated at Daimler Benz before it was shipped to SwRI.

Table 4. Engine Specifications	
Parameter	**Specification**
Engine Type	Four Stroke/I4/DI
Rated Speed, rpm	4200
Power Output, hp	125
Peak torque Speed, rpm	1800-2600
Peak Torque, lb-ft.	220
Induction	Turbocharged
Intercooling	Air-to-Air
Exh. Restriction, in. Hg.	11.0-at rated engine conditions
Int. Restriction, in. water	16.5-at rated engine conditions
Fuel System	electronically controlled, high pressure common rail with pilot injection

C. Test Setup

The test engine was installed in a test cell capable of transient operation. The installation utilized hardware provided by Daimler Benz for dynamometer testing of this engine. The stock intake system was used, and an exhaust system was fabricated to route engine exhaust to a CVS dilution tunnel. Exhaust backpressure was set to Daimler Benz specifications at rated power. At the recommendation of Daimler Benz, the engine was operated with the factory standard transmission attached, locked in fourth gear. The test cell installation is shown in Figure 4.

D. Test Procedures

1. Steady-State Test Points

Engine dynamometer testing was performed for the 13, steady-state, speed/load points listed in Table 5. The measurements were performed at absolute torque settings for all seven fuels across all 13 test modes except for mode 7, which was run at 100-percent torque. Operating the engine at absolute speed/load points allowed emissions comparisons to be made based on differences in fuel consumption and chemistry, not on power variations resulting from density differences.

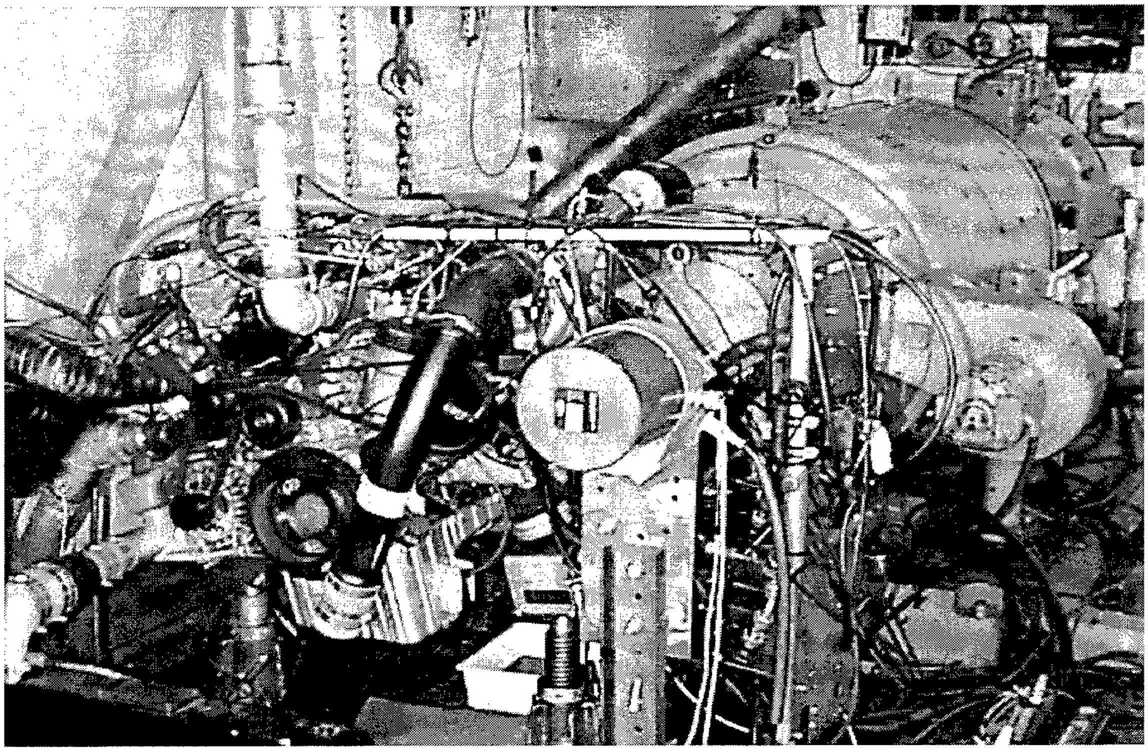

Figure 4a. Front View of the OM 611 Engine

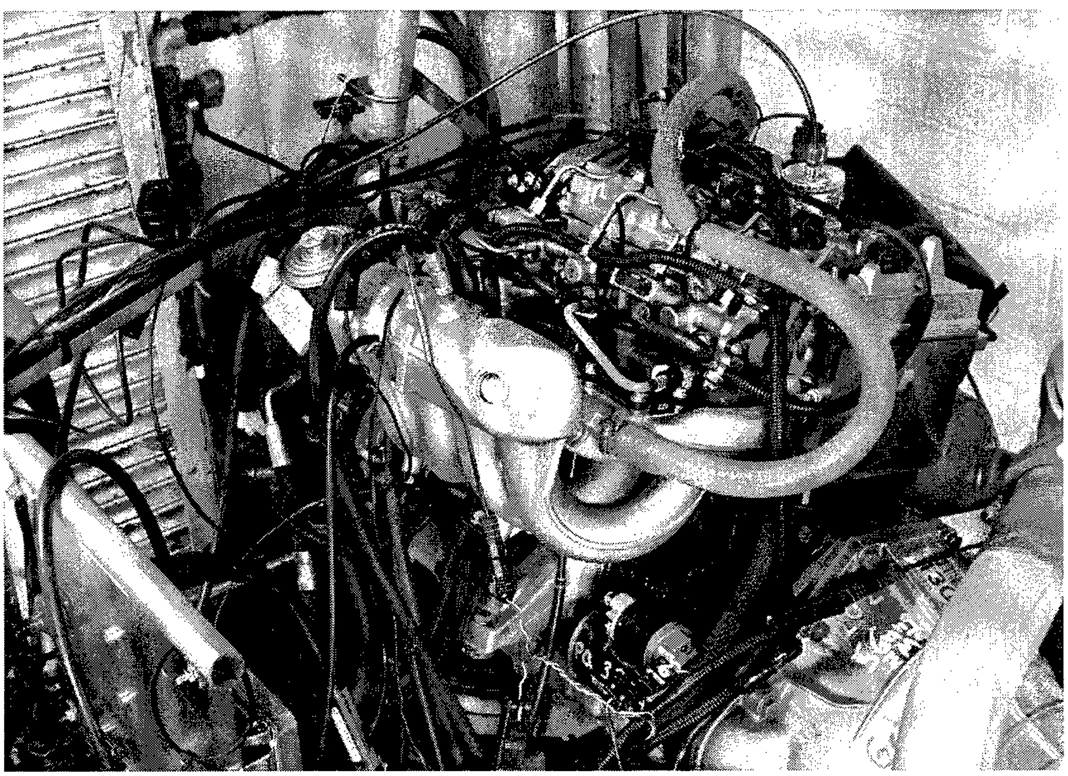

Figure 4b. Top View of the OM 611 Engine

Table 5. Steady-State Test Points			
Engine Mode	Engine Speed (RPM)	BMEP (bar)	OM611 Equivalent Torque (ft-lb)
M1	4200	9.3	117
M2	4200	6.2	78
M3	3400	8.8	111
M4	2600	13.1	166
M5	2600	8.8	111
M6	2300	4.2	53
M7	2000	17.5	100 %
M8	2000	15.0	189
M9	2000	8.8	111
M10	2000	2.0	25
M11	1500	2.62	33
M12	900	0.1	1-2
M13	765	0.1	1-2

Figure 5 shows the 13 speed/load points in relation to the operating characteristics of the OM 611. Note that modes 5, 6, and 9 – 12 lie in the EGR region. In addition, modes 10 – 13 are in a region where the intake swirl is increased. A detailed analysis of the effects of the different emissions control strategies is beyond the scope of this work, but it is useful to keep these facts in mind when looking at the results section.

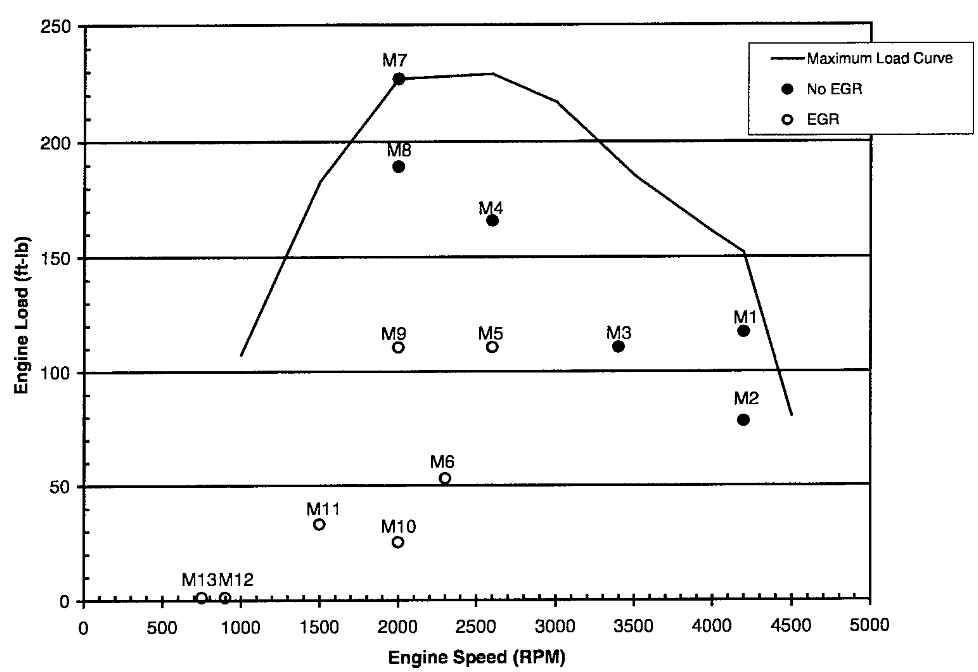

Figure 5. Test Points

2. Test Sequence

On each of the seven test fuels, triplicate, 13-mode test sequences were performed for a total of 21, 13-mode, steady-state tests. The test matrix was fully randomized except for the DMM blend. The DMM blend was run three times (back-to-back) at the end of the test program. The overall test plan is provided in Table 6. The EPA 13-mode, steady-state test procedure was used as the guideline for engine operating procedures and exhaust emissions sampling and analysis. Longer sampling periods were needed during the low-speed, low-load modes (10-13) to collect a measurable amount of particulate on the filter media.

Table 6. Test Plan

Step	Description
1	If needed, flush fuel system with new fuel and change fuel filter.
2	With each fuel change, operate engine at Mode 1 for 30 minutes to condition CVS and PM sampling systems.
3	Confirm proper engine operation at rated power and maximum torque.
4	Proceed to Mode 1.
5	Stabilize engine for 5 minutes.
6	Sample exhaust emission for specified time.
7	Proceed to next mode.
8	Repeat Steps 5 through 7 for the remaining test modes.
9	Repeat Steps 1 through 8 until all fuels are tested.

Mode Sample Times	
Mode	**Time (seconds)**
M1	300
M2	300
M3	300
M4	300
M5	300
M6	300
M7	300
M8	300
M9	300
M10	600
M11	600
M12	1200
M13	1200

Fuel Test Schedule	
Day	**Fuel**
1	2D
2	FT20
3	FT100
4	LS
5	B20
6	FT100
7	LS
8	FT20
9	LS
10	2D
11	B20
12	CARB
13	B20
14	CARB
15	FT20
16	CARB
17	2D
18	FT100
19	DMM15
20	DMM15
21	DMM15

3. Emissions Measurement

A constant volume sampler (CVS) was used to dilute engine exhaust prior to sampling. This positive-displacement pump, CVS system included a 23-inch-diameter, stainless-steel dilution tunnel, which was designed for transient testing of heavy-duty diesel engines. Therefore, the lowest available CVS flow rate of 1,000 scfm was used during all testing. This flow rate provided dilution factors ranging from 8 to 165 across all modes. All dilution air was filtered prior to entering the CVS system to minimize levels of particles and hydrocarbons in the background air.

Emissions measured during this project included total hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NOx), and particulate matter (PM). Hydrocarbons were measured using continuous dilute sampling techniques employing a heated flame ionization detector (HFID). Carbon monoxide and CO2 were determined using integrated proportional dilute gaseous samples analyzed with non-dispersive infrared (NDIR) instruments. Dilute NOx was measured continuously with a chemiluminescence instrument. A number of practice 13-mode tests were conducted to establish the required analyzer ranges for measurement of HC and NOx, and to determine mode times to ensure sufficient loading of the particulate filters.

Total PM levels were determined by collecting particulate matter on a set of 90 mm Pallflex filters, which were weighed before and after each test mode. A secondary dilution tunnel, linked to the primary tunnel via a transfer tube, was equipped with a holder for the particulate filters. A sample pump and a gas meter constituted the main equipment required for the sampling of particulate matter. The system included temperature and pressure measurement for accurate calculation of particulate sample flow. Both of the 90-mm Pallflex filters (primary and secondary) were held at a temperature of ≤ 125°F.

In addition to total particulate mass, size-segregated particulate mass was measured during one of the three 13-mode tests conducted with each fuel. Particulate size distribution was measured with a Model 110 Micro-Orifice Uniform Deposit Impactor (MOUDI) using an isokinetic sampling probe. The flow rate through the MOUDI was 30

L/min. Stages 3–10 were used to collect particulate mass at equivalent aerodynamic diameter cut-off ranges of 6.2, 3.1, 1.8, 1.0, 0.54, 0.31, 0.17, 0.09, and 0.056 μm. The particles were collected on uncoated, 47-mm foil substrates. The MOUDI is pictured in Figure 6.

The MOUDI operates in the same manner as any inertial cascade impactor with multiple nozzles. At each stage, jets of particle-laden air impinge upon an impaction plate. Particles larger than the cut size of that stage cross the air streamlines and remain on the impaction plate. Smaller particles with less inertia cannot cross the streamlines and proceed to the next stage. Smaller nozzles with higher air velocity collect finer particles. The process continues through the cascade impactor until the smallest particles are collected on the final glass-fiber backup filter. By rotating every other stage of the impactor and holding the others stationary, every nozzle plate/impaction plate combination has relative rotation. This rotation allows the MOUDI to achieve near-uniform particle deposition.

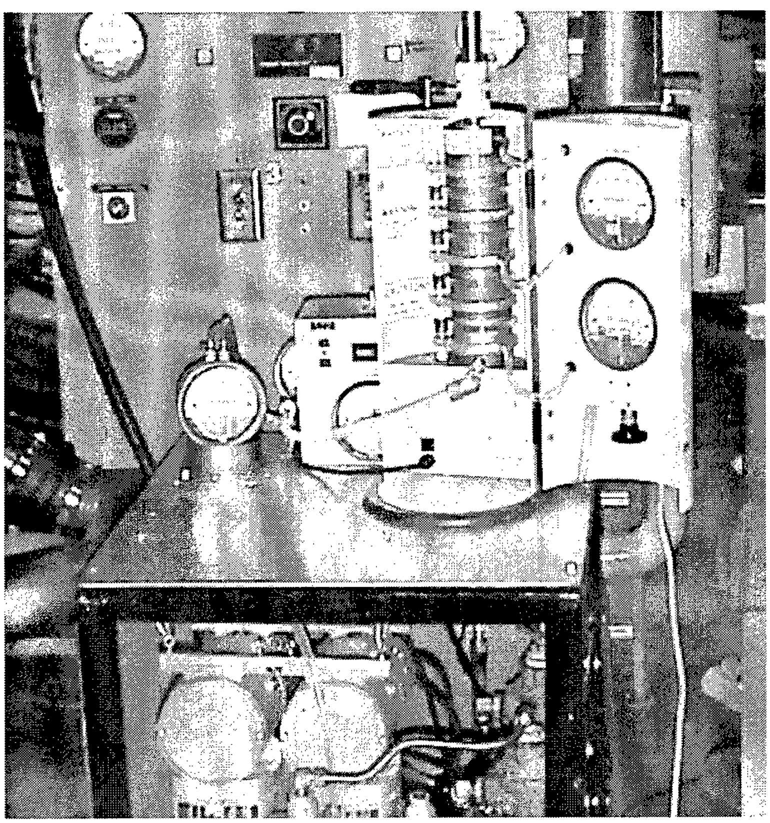

Figure 6. **<u>Micro-Orifice Uniform Deposit Impactor (MOUDI)</u>**

IV. RESULTS AND DISCUSSION

This section presents the engine performance, data analysis, and results of the emissions testing. Engine performance was analyzed through measurement of the full-load engine torque and operating conditions for each fuel. The specific fuel consumption and thermal efficiency at each of the 13 modes were also considered for each fuel. Statistical analyses of the emissions data were conducted to determine the significance of observed differences. Emissions results are presented as a comparison of the seven test fuels. Tabular summaries of the emission rates and indices are provided in Appendix A. The emission indices are the emission rates divided by the fuel consumption rate. Individual test results are provided in Appendix B.

A. Engine Performance

Full-load engine torque and operating conditions were measured for each fuel at nine points across the engine's operating range. Results are presented in Figure 7. The raw data from these evaluations are included in Appendix C. Except for the DMM blend, there was little power difference among the fuels. While operating on the DMM blend, slightly less torque was observed near 1500 rpm, while more power was produced above 3000 rpm.

In general, the engine operated satisfactorily on all fuels. However, operation on DMM15 required special precautions. Due to its low initial boiling point (42°C), DMM would boil out of solution in the fuel return line and in the day tank. To alleviate this problem, the fuel return line was configured with a simple heat exchanger that consisted of a coiled tube submerged in a cooler filled with crushed ice. Figure 8 shows this configuration without the ice. This setup kept the fuel in the day tank cool enough to avoid boiling the DMM out of solution. However, DMM fumes from the fuel were always noticeable in the test cell while the engine was running.

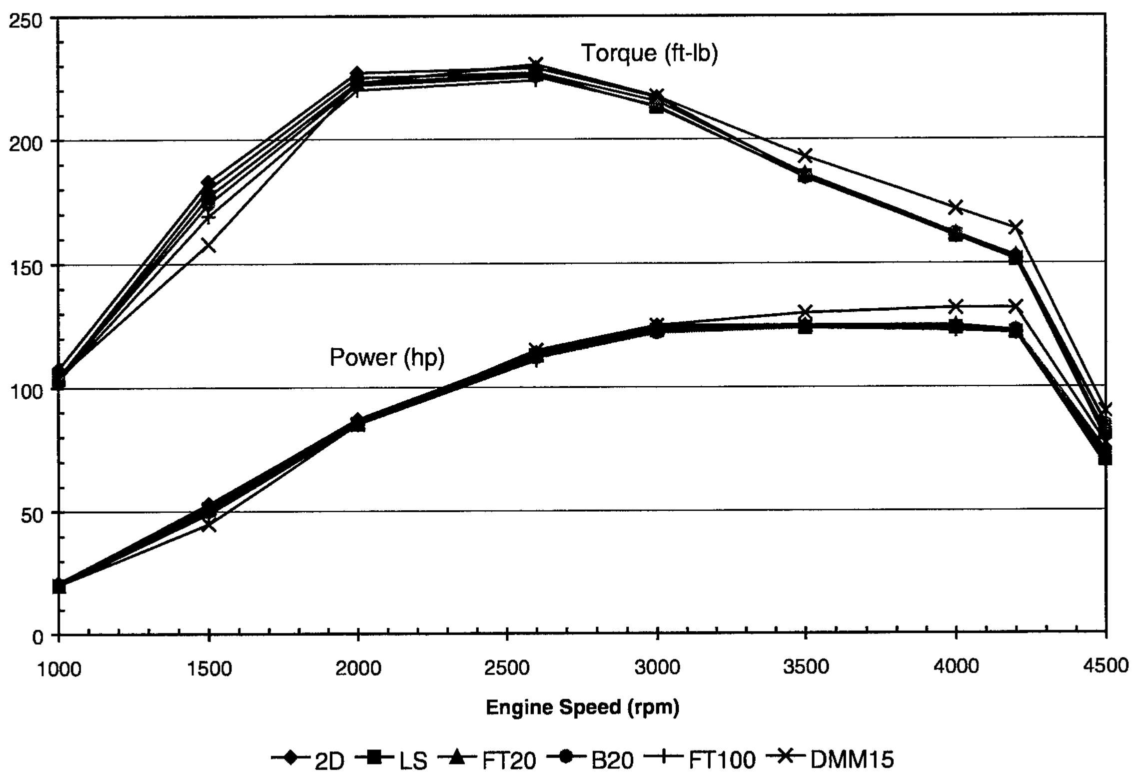

Figure 7. <u>Comparison of Full Load Engine Torque with Different Fuels</u>

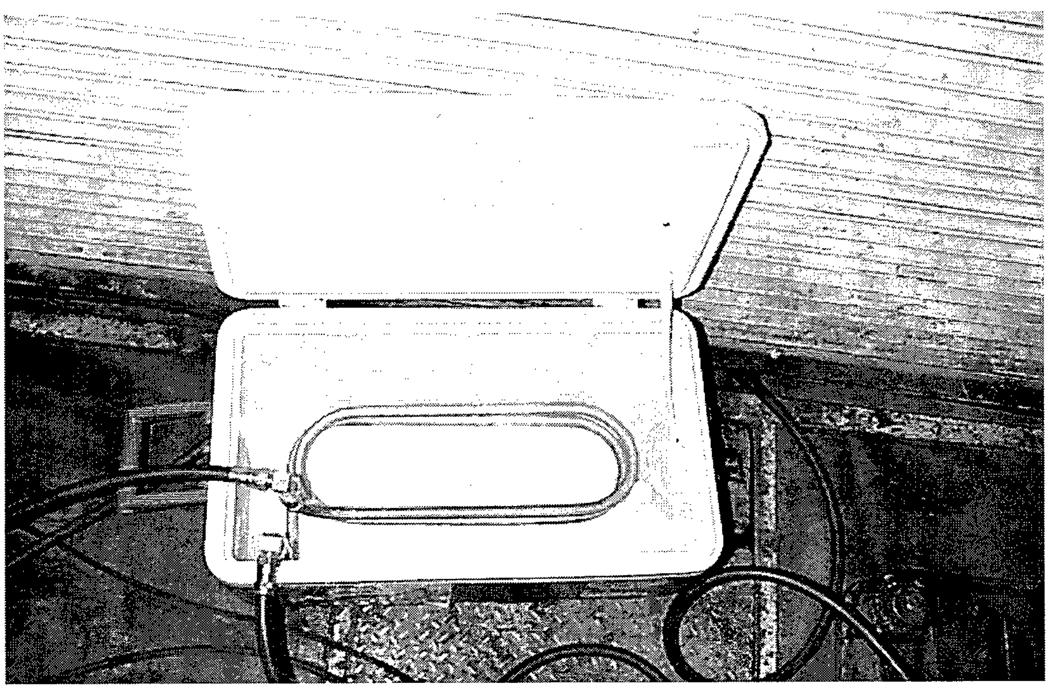

Figure 8. <u>Heat Exchanger Used in Fuel Return Line with DMM Blend</u>

Due to the high pressure in the common fuel rail, the DMM would stay in solution in the rail during typical testing despite the elevated temperatures. However, during practice runs with this fuel, the engine was operated with the test-cell overhead door open to minimize the DMM levels in the cell. When the engine was operating in the afternoon, while the sun was shining directly on the top of the engine, it did not run smoothly, and power was about ten-percent low at rated speed. It is suspected that the additional heating of the fuel rail from the sun was enough to cause the DMM to vaporize in the rail. This additional heating from the sun was not a problem during actual testing, because the test cell temperature was controlled and the overhead door was kept closed.

The engine showed very little variation in brake-specific fuel consumption (BSFC) and thermal efficiency for the seven test fuels. The BSFC and thermal efficiency are presented in Figures 9 and 10. The BSFC of the DMM blend is slightly higher than the other fuels at modes 1 and 2, but no consistent trends in fuel consumption are evident across all 13 modes. Similarly, the achievable thermal efficiencies of the alternative fuels did not vary significantly at any point in the test sequence.

B. Statistical Analysis of Emissions Data

To determine which observed differences were significant, 14 statistical analyses were performed for each of the four measured exhaust emissions (CO, HC, PM and NOx). Emissions measured at each of 13 different modes were analyzed individually by mode, and a final analysis was performed using a "composite mode," calculated by averaging the emissions results of all 13 modes. Each average emission was compared among the seven test fuels using the analysis of variance (ANOVA) statistical procedures [16]. If significant differences in the average emission rates were present, a Tukey's multiple comparison procedure was used to discriminate the average emission rates among the seven fuels. All statistical comparisons were made at the five-percent level of significance. In four of the ANOVA analyses, the assumption of equal variance of the residuals across the fuel groups was violated. In these cases a Kruskal-Wallis nonparametric technique was used to compare the median of the emissions among the fuels [17].

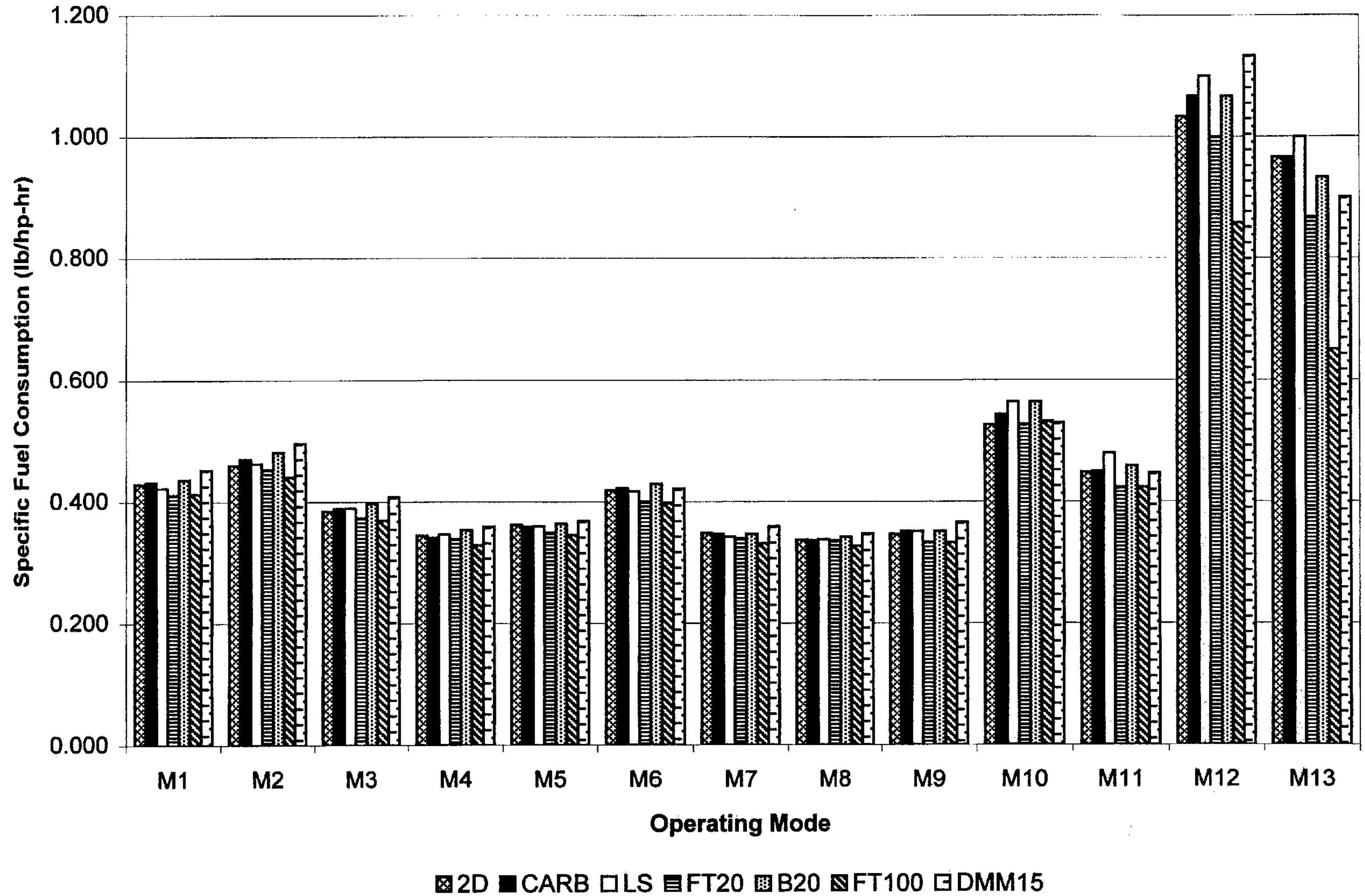

Figure 9. Specific Fuel Consumption

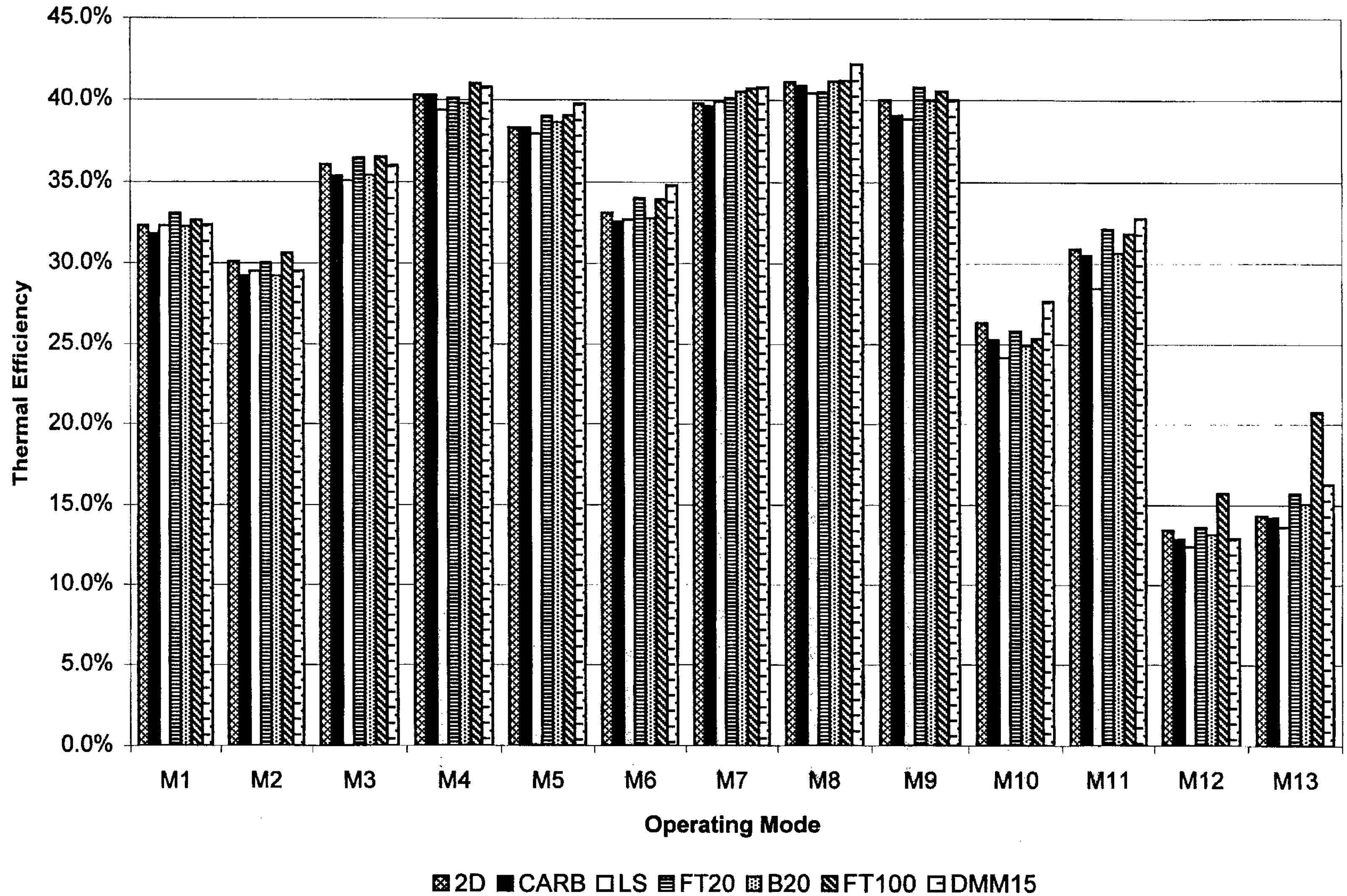

Figure 10. Engine Thermal Efficiency

Graphic representations of the ANOVA and nonparametric Kruskal-Wallis comparison tests for each of the 13 individual modes, as well as the average "composite mode," are provided in Appendix D. These graphs include the means and the 95-percent Tukey confidence intervals about the means for all seven fuels. Overlapping intervals indicate no significant difference in the average emission at the 95-percent confidence level. Non-overlapping intervals demonstrate fuels that produce statistically significant differences in average emissions. For modes that used a nonparametric comparison of the fuels, the medians and their corresponding 95-percent confidence intervals are displayed.

C. Particulate Matter (PM) and Oxides of Nitrogen (NO_x) Emissions

The particulate matter and NOx emissions from diesel engines are of primary concern. For this reason, the analysis of the data focused on these two emissions and the NOx/PM trade-off. By reviewing the chemical properties in Table 2, it would be expected that the fuels with reduced aromatics and sulfur content as well as high cetane numbers would produce lower PM levels. An ability to control PM levels without raising the NOx emissions would give engine designers more leverage in reducing emissions.

The particulate matter emissions are shown in Figure 11 as a fraction of the 2D emissions level. The 2D level is indicated by the bold line at 1.00 (100 percent). The columns in Figure 11 represent the average of the three tests conducted for each fuel. The LS, FT20, B20, FT100 and DMM15 fuels show a benefit in particulate emissions in comparison to the 2D fuel. The DMM15 fuel reduced particulate emissions by between 45 to 83 percent from the 2D value across modes 1–13. The FT100 also produced a significant benefit in PM emissions, with reductions ranging from 31 to 75 percent. The percent change from the 2D fuel is summarized for each mode in Table 7. Statistically significant reductions in particulates are achieved throughout most of the test modes.

The NOx data is presented as a fraction of the 2D baseline emissions in Figure 12. NOx levels are close to the 2D value for modes 1–9. Modes 10–12 show large average reductions in NOx. However, these reductions are not statistically significant (Table 8). Statistically significant reductions in NOx were observed at modes 1, 7, and 8 (relatively high-load conditions). Oxides of nitrogen emissions tended to increase (in some cases significantly) relative to the 2D baseline at modes 5, 6, and 9. These modes are at the edge of the operating range for EGR, and the NOx changes may be artifacts of the engine calibration.

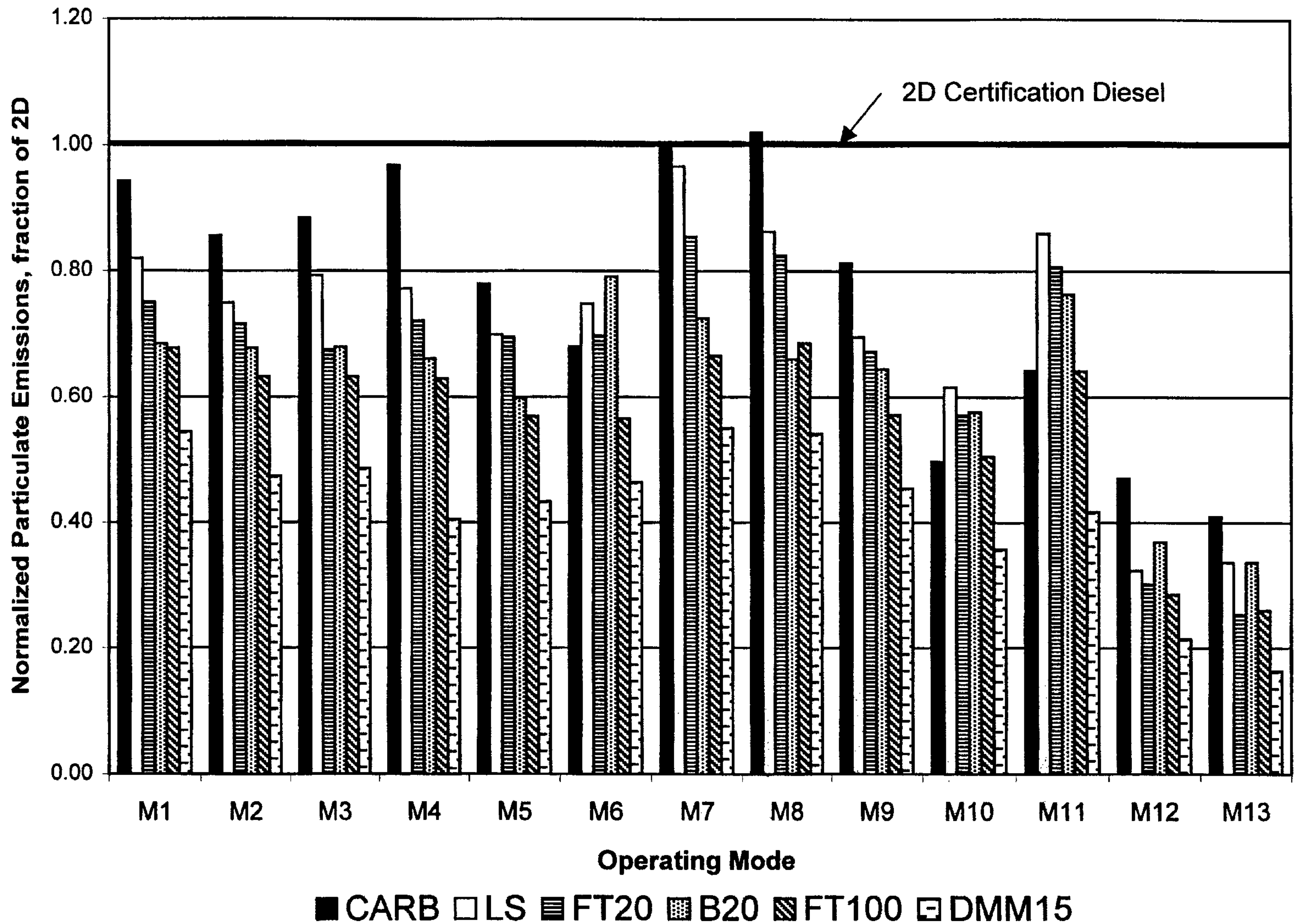

Figure 11. Normalized Particulate Emission Rates shown as a Fraction of the 2D Particulate Emissions Rate

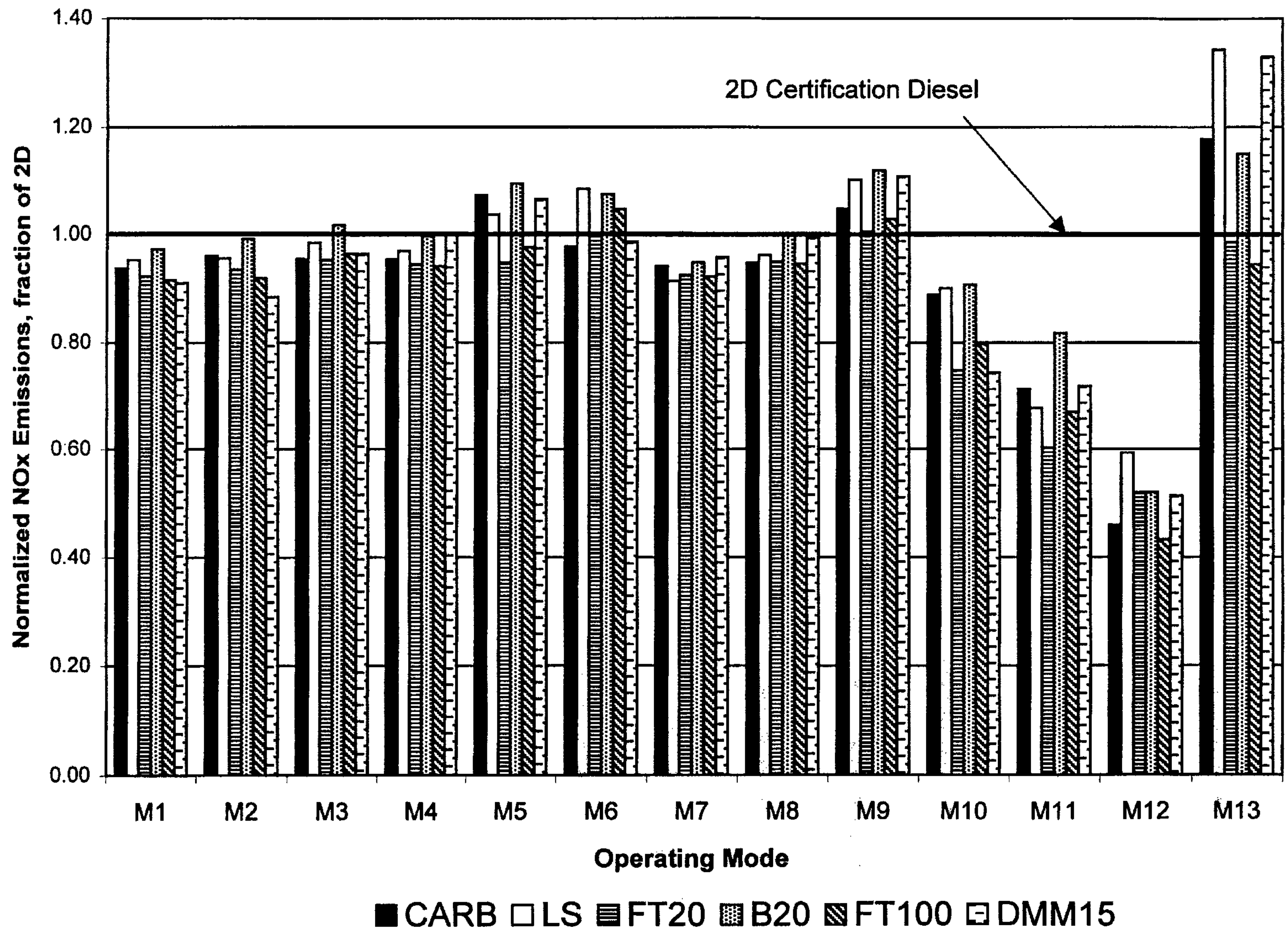

Figure 12. Normalized NOx Emission Rates shown as a fraction of the 2D NOx Emission Rate

Table 7. PM Percent Change from 2D Baseline						
Mode	Fuel					
	CARB	LS	B20	FT20	FT100	DMM15
M1	***-6%***[a]	***-18%***	***-32%***	***-25%***	***-32%***	***-46%***
M2	***-14%***	***-25%***	***-32%***	***-28%***	***-37%***	***-53%***
M3	***-11%***	***-21%***	***-32%***	***-32%***	***-37%***	***-51%***
M4	-3%	***-23%***	***-34%***	***-28%***	***-37%***	***-60%***
M5	***-22%***	***-30%***	***-41%***	-31%	***-43%***	***-57%***
M6	-31%	-25%	-21%	-30%	***-43%***	***-54%***
M7	1%	-3%	***-27%***	***-14%***	***-33%***	***-45%***
M8	3%	-14%	***-34%***	***-17%***	***-31%***	***-46%***
M9	***-19%***	***-31%***	***-36%***	***-33%***	***-43%***	***-54%***
M10	***-50%***	-38%	***-42%***	***-43%***	***-50%***	***-64%***
M11	***-36%***	-14%	-24%	-19%	***-36%***	***-58%***
M12	***-50%***	***-67%***	***-63%***	***-71%***	***-75%***	***-75%***
M13	***-59%***	***-66%***	***-66%***	***-72%***	***-72%***	***-83%***
Composite	***-13%***	***-21%***	***-32%***	***-27%***	***-37%***	***-52%***
[a] Values in bold italics are statistically significant						

Table 8. NOx Percent Change from 2D Baseline						
Mode	Fuel					
	CARB	LS	B20	FT20	FT100	DMM15
M1	***-6%*** [a]	***-5%***	-3%	***-8%***	***-8%***	***-9%***
M2	-4%	-4%	-1%	-6%	-8%	***-11%***
M3	-4%	-2%	2%	-5%	-4%	-4%
M4	***-5%***	-3%	-0%	***-5%***	***-6%***	0%
M5	7%	4%	10%	-5%	-2%	7%
M6	-2%	***8%***	***7%***	-0%	5%	-1%
M7	***-6%***	***-9%***	***-5%***	***-7%***	***-8%***	***-4%***
M8	***-5%***	-4%	-0%	***-5%***	***-5%***	-1%
M9	5%	10%	12%	1%	3%	11%
M10	-11%	-10%	-9%	-25%	-20%	-26%
M11	-29%	-32%	-18%	-40%	-33%	-28%
M12	-54%	-41%	-48%	-48%	-57%	-49%
M13	18%	34%	15%	-1%	-5%	33%
Composite	***-4%***	-3%	-0%	***-6%***	***-6%***	***-4%***
[a] Values in bold italics are statistically significant						

Figure 13 summarizes the PM and NOx emissions results. Normalized results are presented for the "composite mode" for each fuel. The 2D fuel has a value of 1.00 (100 percent) for both PM and NOx. The remaining fuels are displayed as a fraction of the 2D value. The error bars on the chart indicate the 95-percent confidence intervals for this 13-mode average. All six alternative fuels produced a significant reduction in PM in comparison to the 2D fuel. The PM reduction is achieved with no significant increases in NOx. DMM15 shows that the largest average reduction in PM of 52 percent. Significant benefits were also achieved with the FT100 (37-percent reduction), B20 (32-percent reduction), and FT20 (27-percent reduction) fuels.

Because the low sulfur (LS) fuel is the base for the three blended fuels (FT20, B20, DMM15), it is informative to look at the changes in PM and NOx achieved by the these three fuels in comparison to the LS fuel. Figure 14 shows the NOx and PM results as a fraction of the LS fuel. The DMM blend produces a 38-percent reduction from the LS fuel. Fuels B20 and FT20 show 14- and 7-percent reductions, respectively. The variations in NOx among the FT20, B20, and DMM15 fuels were not significantly different from the LS fuel.

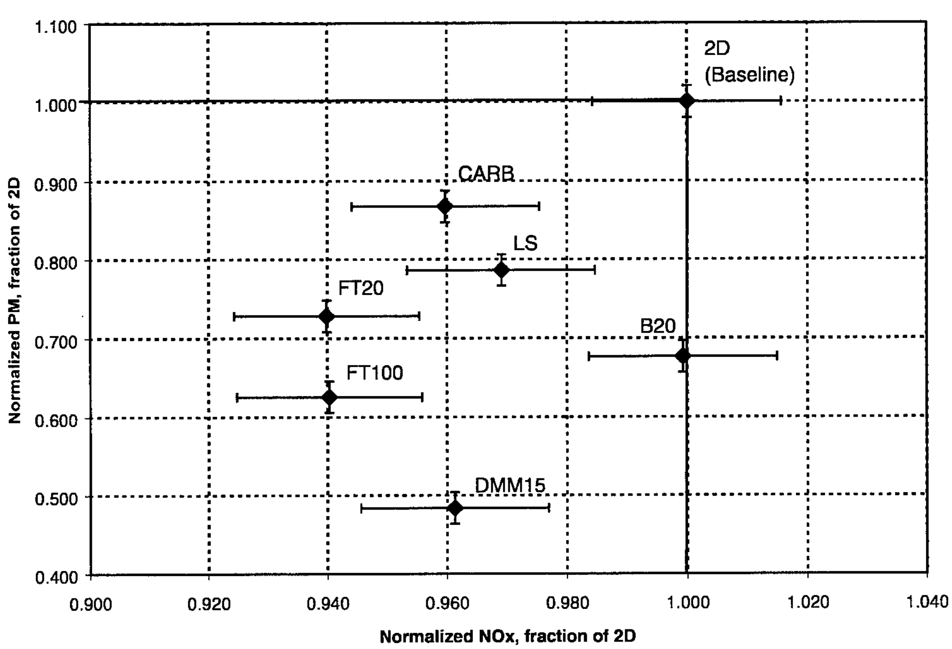

Figure 13. NOx versus PM emissions for composite, 13-mode average. Alternative fuels are shown as a fraction of the 2D results.

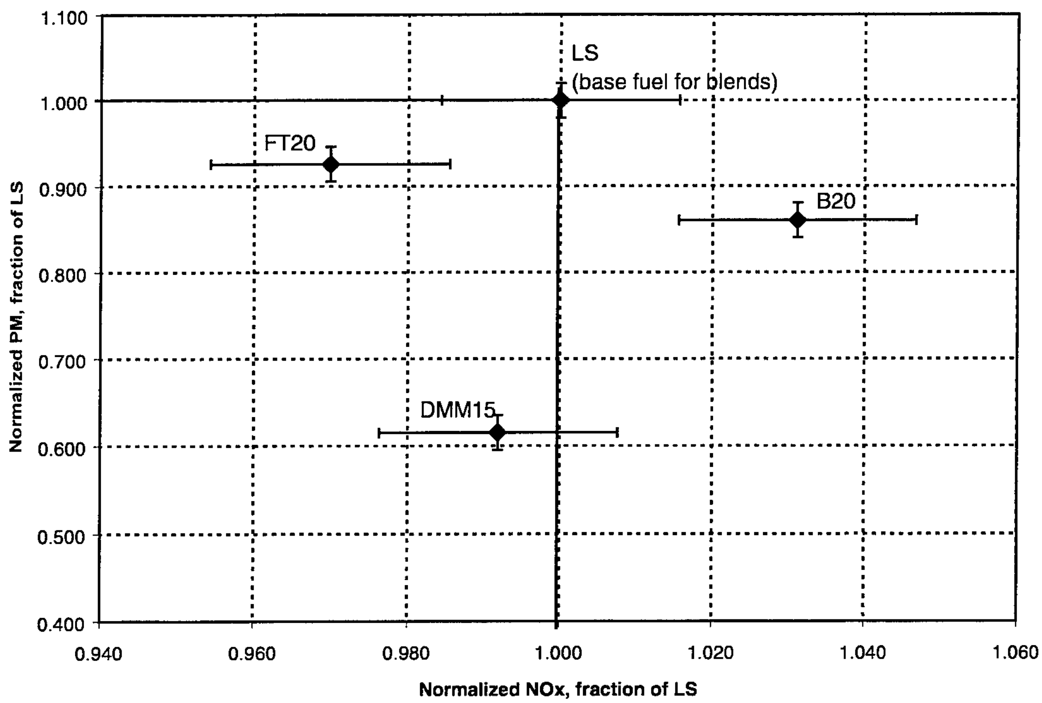

Figure 14. **NOx versus PM emissions for blended fuels in comparison to the low-sulfur (LS) base fuel.**

D. PM Size Distribution

Average total-particulate-mass emission rates measured with the MOUDI impactor were calculated by adding the masses collected on individual stages. These values were then compared to total-particulate emission rates determined with 90-mm filters. Average PM emission rates determined with the MOUDI were 83 to 92 percent of the values determined with the 90-mm filters, indicating that a majority of the particulate entering the MOUDI was collected on the plates and the backup filter.

Size-segregated particulate mass emission fractions over the "composite mode" are provided in Figure 15. Results from individual modes are provided in Appendix E. In order to compare the particle size distributions by fuel independent of the total particulate emissions rate, these data are presented as percent of total mass measured for each individual size bin. This data indicates no significant differences in particulate-mass size distribution among the seven fuels. This trend is consistent across all individual modes.

For all fuels, approximately 40 percent of all measured particulate mass was between 0.18 and 0.10 μm mean aerodynamic diameter. Approximately three-quarters of measured particulate mass was between 0.32 and 0.06 μm for all fuels, and about 97 percent of all measured mass was less than 2.0 μm in size. Approximately 10 percent of the particulate mass was less then 0.06 μm.

E. Total Hydrocarbon (HC) Emissions

Because emissions of total hydrocarbons (HC) are more readily controlled with aftertreatment devices, this gaseous emission is of less concern than the NOx and PM results. Figure 16 shows the average HC results as a fraction of the 2D emissions for each mode. The trends in HC emissions is not as consistent across the 13 modes as the results for PM and NOx emissions. HC levels at modes 7 and 8 are higher than the 2D emissions for FT20, B20 and DMM15. However, the statistical analysis indicates that HC differences at these modes are not significantly different. With the exception of the CARB fuel, modes 10, 11, 12 and 13 generally have decreased HC emissions for the alternative fuels. The percent reductions in HC are summarized in Table 9.

Table 9. HC Percent Change from 2D Baseline

Mode	Fuel					
	CARB	LS	B20	FT20	FT100	DMM15
M1	20%	-6%	-21%	2%	-9%	40%
M2	9%	-22%	-8%	-24%	-22%	***-27%***[a]
M3	8%	-25%	-7%	-24%	-26%	-20%
M4	14%	-13%	-6%	-20%	-27%	16%
M5	3%	-36%	***-48%***	-35%	***-56%***	-11%
M6	-6%	***-53%***	***-37%***	***-42%***	***-55%***	***-29%***
M7	20%	-11%	20%	7%	-2%	39%
M8	41%	-21%	31%	31%	0%	69%
M9	21%	-67%	3%	-15%	-61%	30%
M10	-3%	***-72%***	***-64%***	***-65%***	***-77%***	-36%
M11	-17%	***-74%***	-46%	-53%	***-73%***	-47%
M12	9%	***-87%***	-39%	***-84%***	***-88%***	-63%
M13	-47%	***-80%***	***-5%***	***-95%***	***-92%***	***-82%***
Composite	0%	***-47%***	***-31%***	***-42%***	***-50%***	***-24%***

[a] Values in bold italics are statistically significant

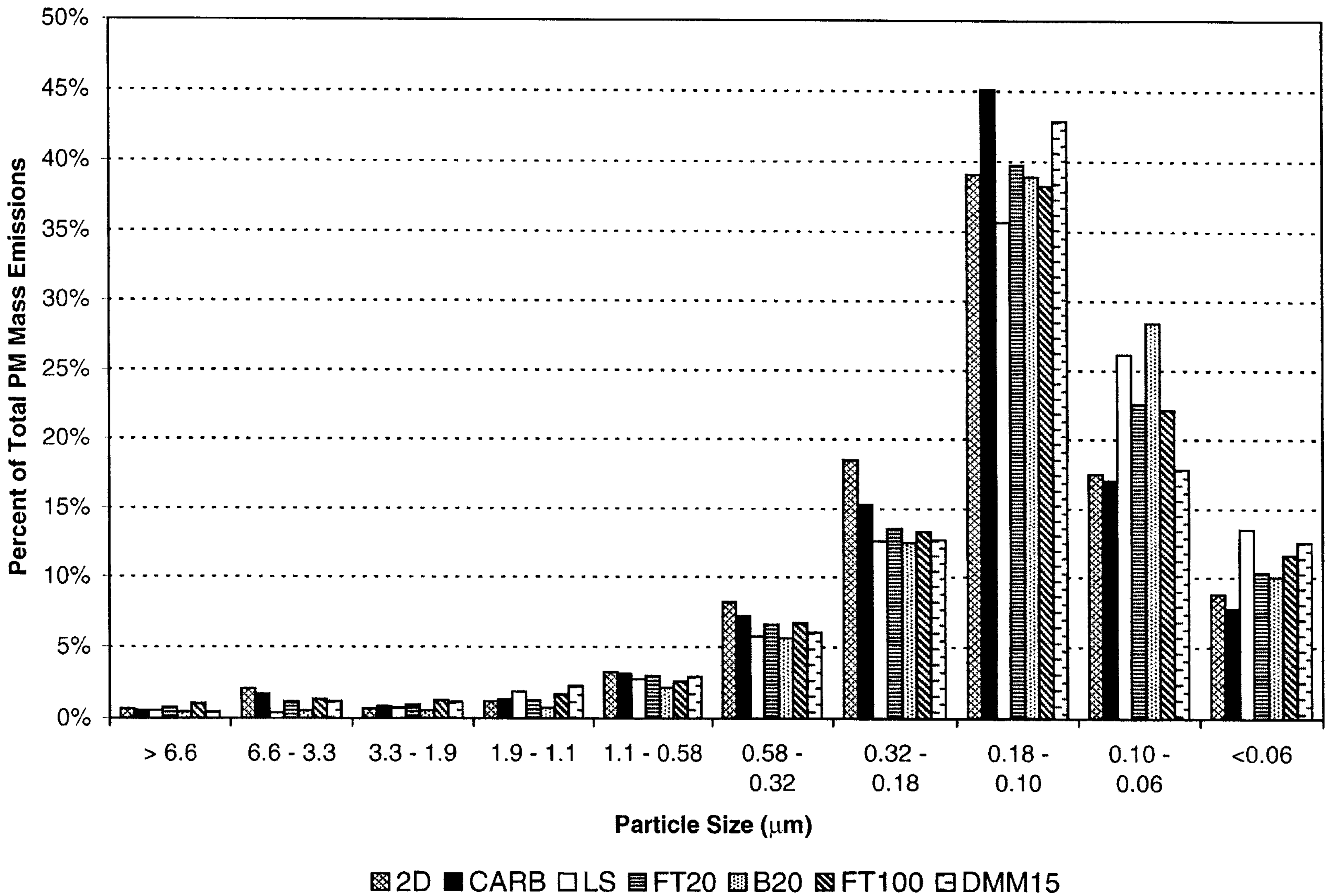

Figure 15. Composite Size Segregated particle Mass Fractions

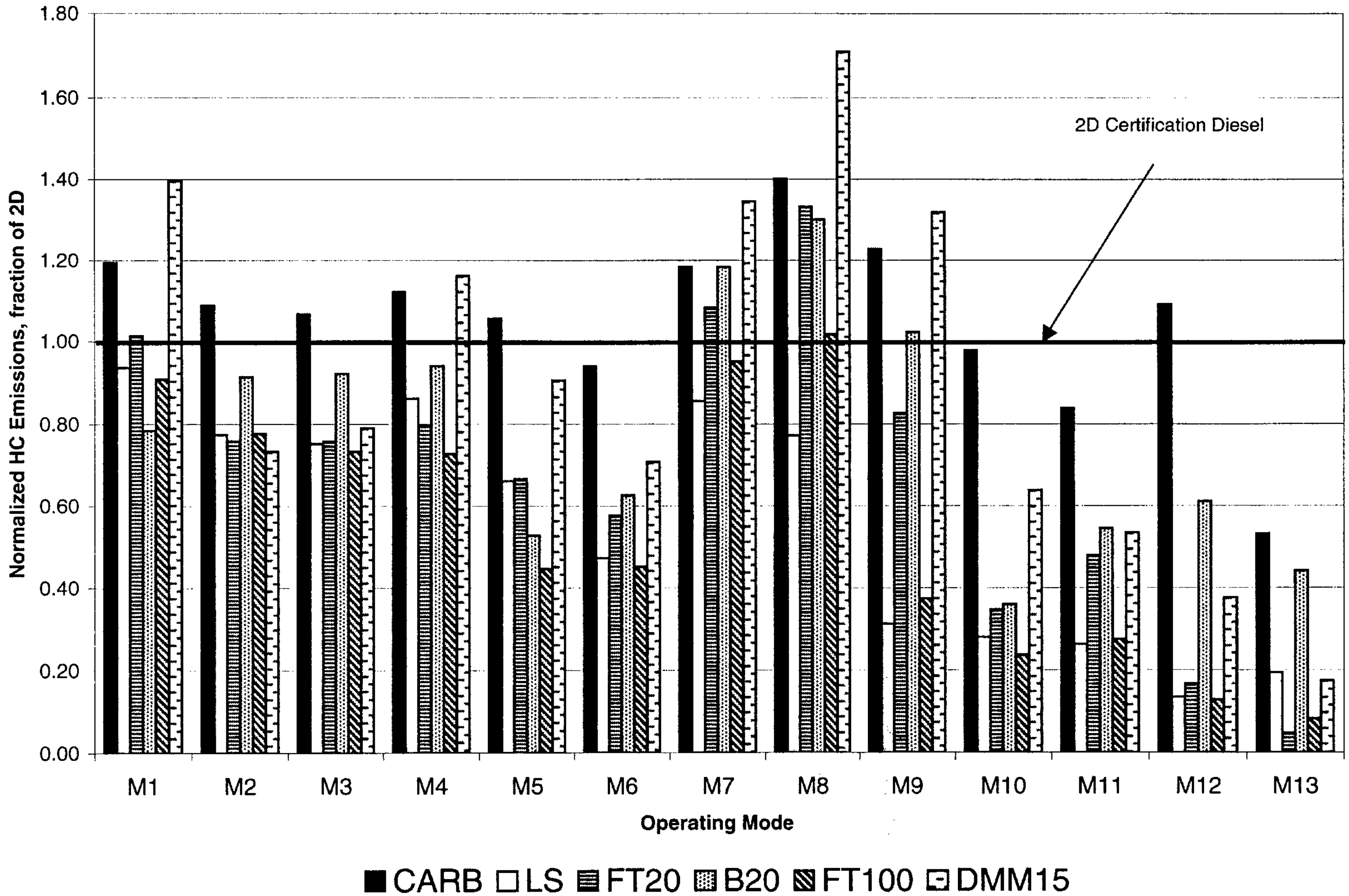

Figure 16. <u>Normalized total Hydrocarbon Emission Rates as a Fraction of the 2D Emission Rate</u>

As a summary of the HC data, Figure 17 presents the normalized, 13-mode average for each fuel. Once again, the error bars represent the 95-confidence interval for this "composite mode." The 2D and CARB fuels have similar HC levels. The remaining five fuels reduce HC emissions to levels between 50 and 76 percent of the 2D baseline fuel. Note that the HC level for these five fuels are not statistically different from each other.

The reduction in HC achieved for the 13-mode average by the LS, FT20, B20, FT100 and DMM15 fuels may be explained by the differences in cetane number. The 2D and CARB fuels have cetane values of 46 and 45, respectively, while the cetane number of the remaining fuels ranges from 63 to 84.

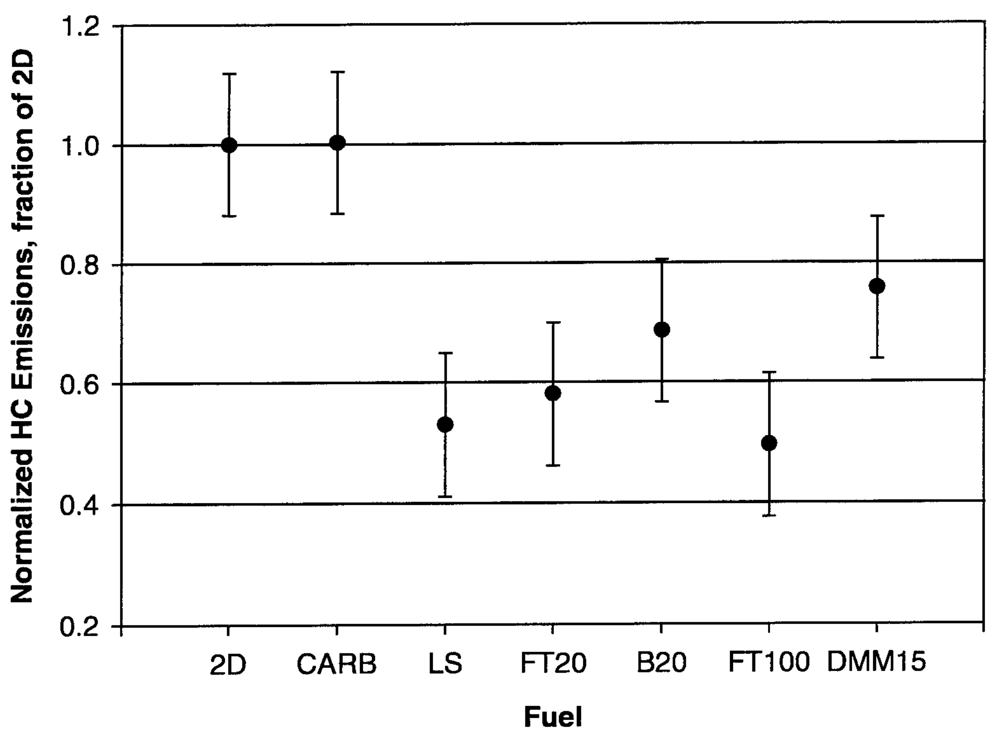

Figure 17. **<u>Composite Hydrocarbon Emission Rates, with 95 Percent Confidence Intervals</u>**

F. Carbon Monoxide (CO) Emissions

The CO emissions are presented in Figures 18 and 19. The CO emissions would be effectively controlled by the oxidation catalysts, which would normally be included in the exhaust system of the engine. Figure 18 shows the CO emissions as a fraction of the 2D results for the individual modes. With the exception of modes 7 and 8, the six alternative fuels show a reduction in CO in comparison to the 2D fuel. The increases for modes 7 and 8 are not statistically significant (Table 10).

The 13-mode average for the CO data is presented in Figure 19. For this "composite mode," the LS, FT20, B20, FT100, and DMM15 fuels all show a statistically significant reduction in CO emissions. The DMM15 blend is lower than all other fuels, reducing CO emissions by 36 percent. The FT100 fuel reduces average CO by 27 percent, and the LS, FT20 and B20 reduce CO from 15 to 20 percent.

Table 10. CO Percent Change from 2D Baseline

Mode	Fuel					
	CARB	LS	B20	FT20	FT100	DMM15
M1	4%	-5%	-9%	-12%	-9%	4%
M2	***-9%***[a]	***-16%***	***-11%***	***-17%***	***-18%***	***-63%***
M3	***-12%***	***-21%***	***-20%***	***-24%***	***-32%***	***-62%***
M4	-5%	***-15%***	***-16%***	***-17%***	***-20%***	***-31%***
M5	-4%	***-27%***	***-25%***	***-30%***	***-39%***	***-36%***
M6	***-12%***	***-43%***	***-41%***	***-44%***	***-54%***	***-38%***
M7	12%	***23%***	-2%	9%	-3%	-12%
M8	19%	16%	-2%	15%	1%	15%
M9	-5%	***-28%***	***-23%***	***-27%***	***-35%***	***-27%***
M10	-6%	***-52%***	***-51%***	***-55%***	***-66%***	***-38%***
M11	-7%	***-42%***	***-43%***	***-44%***	***-53%***	***-41%***
M12	0%	***-60%***	***-49%***	***-63%***	***-68%***	***-65%***
M13	-19%	***-67%***	***-57%***	***-67%***	***-74%***	***-71%***
Composite	-2%	***-15%***	***-20%***	***-20%***	***-27%***	***-36%***

[a] Values in bold italics are statistically significant

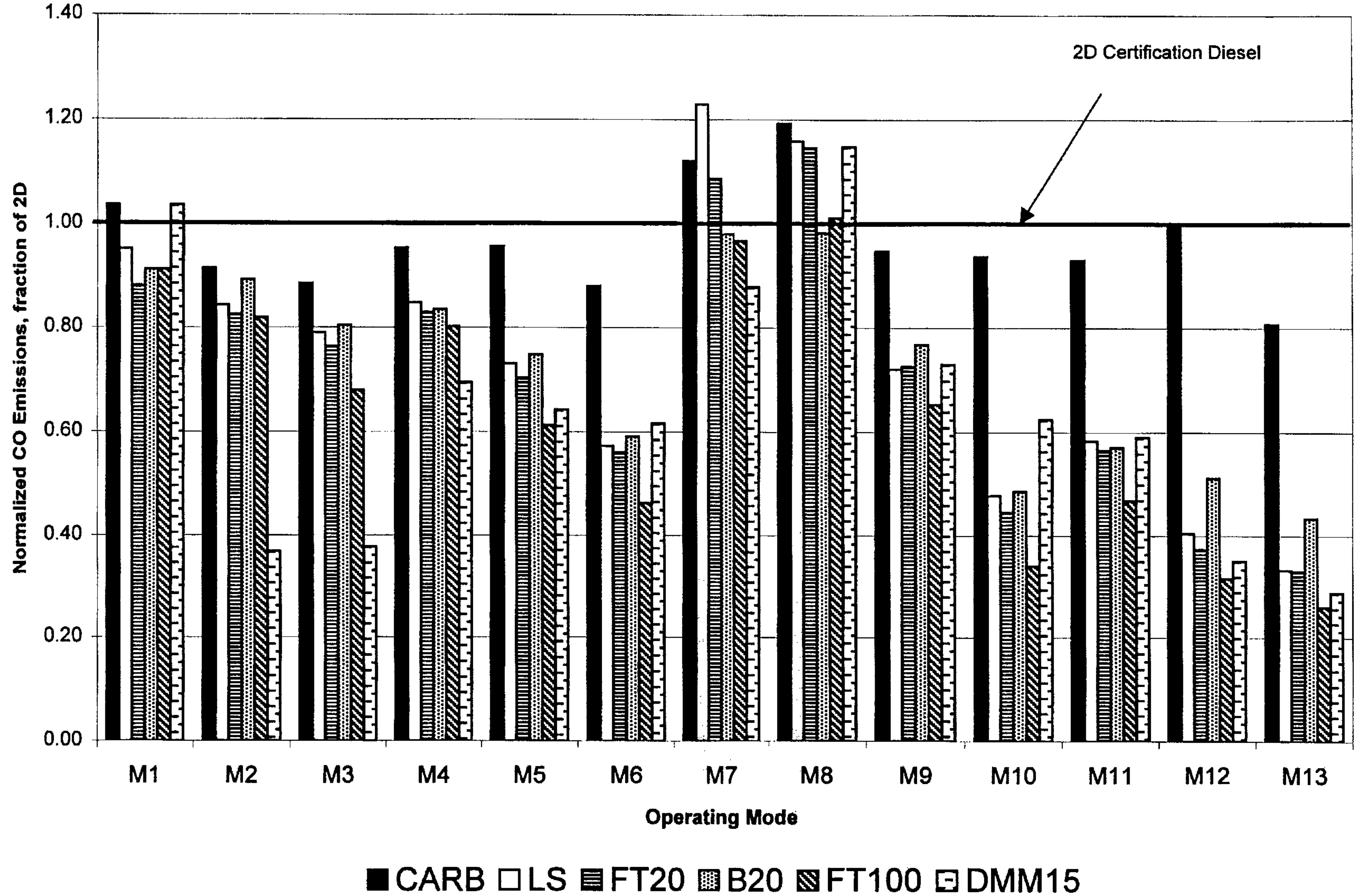

Figure 18. <u>Normalized Carbon Monoxide Emission Rates as a Fraction of the 2D Emission Rate</u>

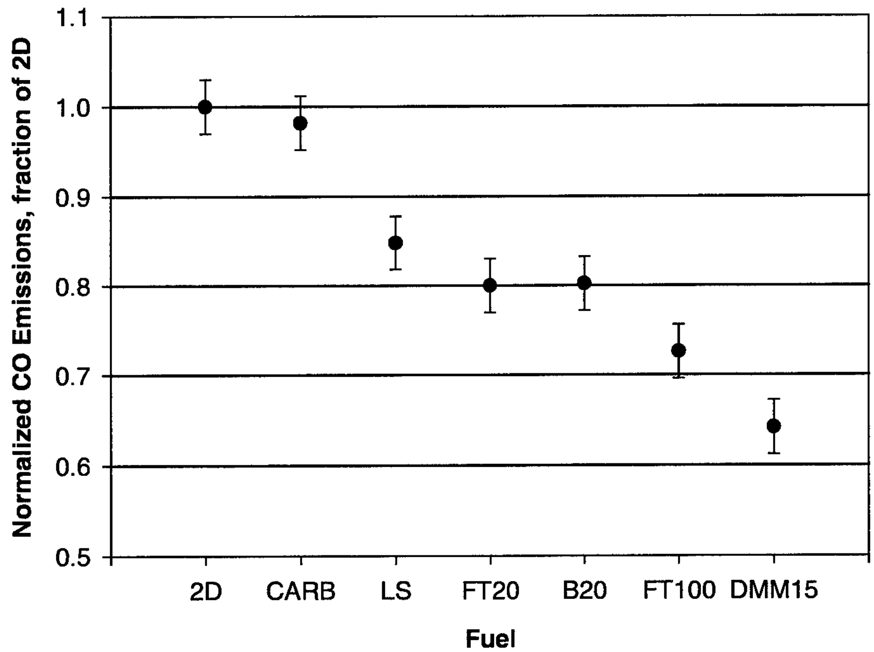

Figure 19. Composite Carbon Monoxide Emission Rates, with 95 Percent Confidence Intervals

V. SUMMARY AND CONCLUSIONS

Gaseous and particulate exhaust emissions were evaluated for a 1998 2.2L, Daimler Benz, direct-injection diesel engine operating on seven diesel and alternative diesel fuel blends. This recently introduced, four-valve-per-cylinder engine is turbocharged and intercooled, and includes a high-pressure, common-rail fuel system with pilot injection. Each fuel was evaluated in triplicate over 13 discrete steady-state modes. In addition, particle size-differentiated mass was determined for each fuel during one of the triplicate 13-mode tests. An EPA certification-grade, on-highway 2-D diesel fuel (2D) served as the baseline fuel. Other fuels tested included the following: pseudo-CARB reference fuel (CARB); low-sulfur diesel (LS); neat Fischer-Tropsch synthetic diesel (FT100); 20-percent Fischer-Tropsch / 80 percent low-sulfur diesel (FT20); 20-percent biodiesel / 80-percent low-sulfur diesel (B20); and 15-percent dimethoxymethane / 85-percent low-sulfur diesel (DMM15).

All of the diesel fuel alternatives provided a statistically significant benefit for PM emissions compared to 2D. PM reductions ranged from 13 to 52 percent for the 13-mode average. There were no statistically significant increases in NOx emission rates with any of the diesel alternative compared to baseline 2D. Furthermore, CARB, FT20, FT100, and DMM15 provided reductions in NOx ranging form 4 to 6 percent on average. All fuels except CARB showed reductions in CO and HC emissions compared to 2D. Percent changes in CO emission rates from the 2D baseline ranged from 15 to 36 percent. Reductions in composite HC emission rates ranged from 24 to 50 percent.

There appear to be no significant differences in particulate-mass size distribution among the seven fuels. For all fuels, approximately three-quarters of measured particulate mass was between 0.32 and 0.06 μm, and about 97 percent of all measured mass was less then 2.0 μm in size. Approximately 10 percent of the particulate mass was less than 0.06 μm.

FT100 and DMM15 provided the greatest benefits in exhaust emission reductions. However, DMM15 had a tendency to boil out of solution without special handling of the fuel. Therefore, it may not be possible to substitute this fuel into existing engines without some modifications to fuel systems. FT100, on the other hand, was easy to utilize in the engine and did not require any modifications to the fuel system.

Based on the results of this test program, it is clear that additional work should be conducted in the area of alternative fuels. These results demonstrate that benefits can be achieved at steady-state operating conditions through the direct substitution of fuels in advanced diesel engines. Additional reductions in emissions may be possible if engine operating parameters such as injection timing and pressure and EGR levels can be adjusted for a specific fuel. Investigations of fuel system and materials compatibility will also be important in future work. Analysis is needed to determine if fuels such as DMM will be compatible with all the materials in a modern engine. The feasibility, safety, and economics of implementing fuels with properties similar to DMM15 will also be important. Wide-scale use of this fuel may require significant changes to current infrastructure.

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APPENDIX A

AVERAGE STEADY-STATE 13-MODE EMISSION TEST DATA

Table A-1. Average Emission Rates (g/hr)					
Mode	Fuel	HC	CO	NOx	PM
1	2D	4.2	57.8	536.3	20.5
	CARB	5.1	59.9	503.1	19.3
	LS	4.0	55.0	511.5	16.8
	B20	3.3	52.7	522.0	14.0
	FT20	4.3	50.9	495.7	15.4
	FT100	3.9	52.7	491.7	13.9
	DMM15	5.9	59.9	488.6	1.1
2	2D	9.1	221.9	352.6	19.6
	CARB	9.9	202.8	339.0	16.8
	LS	7.1	187.1	337.2	14.7
	B20	8.3	198.0	349.6	13.3
	FT20	6.9	183.3	330.1	14.1
	FT100	7.1	181.8	324.4	12.4
	DMM15	6.7	81.7	312.1	9.3
3	2D	5.3	124.9	364.0	10.5
	CARB	5.7	110.5	347.7	9.3
	LS	4.0	98.7	358.5	8.3
	B20	4.9	100.4	370.2	7.1
	FT20	4.0	95.4	347.3	7.1
	FT100	3.9	84.9	351.1	6.7
	DMM15	4.2	47.1	350.9	5.1
4	2D	2.3	44.9	361.0	6.7
	CARB	2.7	42.8	344.7	6.5
	LS	2.0	38.0	350.1	5.1
	B20	2.2	37.5	359.8	4.4
	FT20	1.9	37.2	341.4	4.8
	FT100	1.7	36.0	340.2	4.2
	DMM15	2.7	31.2	361.5	2.7
5	2D	3.0	59.8	149.8	10.8
	CARB	3.1	57.2	160.6	8.4
	LS	1.9	43.7	155.2	7.5
	B20	1.5	44.8	164.0	6.4
	FT20	1.9	42.1	142.1	7.4
	FT100	1.3	36.6	146.3	6.1
	DMM15	2.6	38.4	159.5	4.7

Table A-1 (continued). Average Emission Rates (g/hr)					
Mode	**Fuel**	**HC**	**CO**	**NOx**	**PM**
6	2D	5.3	80.3	40.3	8.9
	CARB	5.0	70.7	39.4	6.1
	LS	2.5	46.0	43.7	6.7
	B20	3.3	47.4	43.3	7.1
	FT20	3.0	45.0	40.2	6.2
	FT100	2.4	37.2	42.2	5.1
	DMM15	3.7	49.5	39.7	4.1
7	2D	1.5	233.6	343.5	13.7
	CARB	1.8	262.0	323.7	13.8
	LS	1.3	287.0	314.1	13.3
	B20	1.8	229.0	325.9	10.0
	FT20	1.6	254.2	318.1	11.8
	FT100	1.4	225.9	317.2	9.2
	DMM15	2.0	205.1	329.2	7.6
8	2D	1.0	69.0	300.6	6.1
	CARB	1.4	82.3	285.1	6.3
	LS	0.8	80.0	289.3	5.3
	B20	1.3	67.8	300.5	4.0
	FT20	1.3	79.1	285.7	5.1
	FT100	1.0	69.8	284.6	4.2
	DMM15	1.6	79.3	298.9	3.3
9	2D	1.1	26.0	137.1	4.8
	CARB	1.3	24.7	143.7	3.9
	LS	0.4	18.8	151.1	3.3
	B20	1.1	20.0	153.5	3.1
	FT20	0.9	18.9	137.9	3.2
	FT100	0.4	17.0	141.0	2.7
	DMM15	1.4	19.0	152.0	2.2
10	2D	10.3	105.0	14.1	2.8
	CARB	10.0	98.3	12.6	1.4
	LS	2.9	50.0	12.7	1.7
	B20	3.7	50.9	12.8	1.6
	FT20	3.6	46.8	10.6	1.6
	FT100	2.4	35.6	11.3	1.4
	DMM15	6.6	65.5	10.5	1.0

Table A-1 (continued). Average Emission Rates (g/hr)					
Mode	**Fuel**	**HC**	**CO**	**NOx**	**PM**
11	2D	4.0	38.8	12.3	2.0
	CARB	3.3	36.1	8.7	1.3
	LS	1.0	22.6	8.3	1.7
	B20	2.2	22.1	10.0	1.5
	FT20	1.9	21.9	7.4	1.6
	FT100	1.1	18.1	8.2	1.3
	DMM15	2.1	22.9	8.8	0.8
12	2D	3.2	27.5	5.0	0.8
	CARB	3.5	27.6	2.3	0.4
	LS	0.4	11.1	3.0	0.3
	B20	2.0	14.1	2.6	0.3
	FT20	0.5	10.3	2.6	0.2
	FT100	0.4	8.7	2.2	0.2
	DMM15	1.2	9.6	2.6	0.2
13	2D	4.9	28.4	2.4	1.0
	CARB	2.6	22.9	2.9	0.4
	LS	1.0	9.4	3.3	0.3
	B20	2.2	12.3	2.8	0.3
	FT20	0.2	9.4	2.4	0.3
	FT100	0.4	7.4	2.3	0.3
	DMM15	0.9	8.2	3.2	0.2
Average	2D	4.2	86.0	201.5	8.3
	CARB	4.3	84.4	193.3	7.2
	LS	2.3	72.9	195.2	6.5
	B20	2.9	69.0	201.3	5.6
	FT20	2.5	68.8	189.3	6.1
	FT100	2.1	62.4	189.4	5.2
	DMM15	3.2	55.2	193.7	4.0

Table A-2. Average Emissions Indices: Grams Emission per Kilogram Fuel					
Average Emission Rates (g emission/kg fuel)					
Mode	**Fuel**	**HC**	**CO**	**NOx**	**PM**
1	2D	0.2	3.1	29.2	1.1
	CARB	0.3	3.2	27.1	1.0
	LS	0.2	3.0	28.0	0.9
	B20	0.2	2.8	28.0	0.7
	FT20	0.2	2.9	28.2	0.9
	FT100	0.2	3.0	27.9	0.8
	DMM15	0.3	3.1	25.2	0.6
2	2D	0.7	16.6	26.3	1.5
	CARB	0.7	15.0	25.1	1.2
	LS	0.5	14.1	25.4	1.1
	B20	0.6	14.4	25.5	1.0
	FT20	0.5	14.1	25.3	1.1
	FT100	0.6	14.4	25.7	1.0
	DMM15	0.5	5.8	22.1	0.7
3	2D	0.4	9.8	28.7	0.8
	CARB	0.4	8.7	27.2	0.7
	LS	0.3	7.7	28.0	0.7
	B20	0.4	7.7	28.4	0.5
	FT20	0.3	7.9	28.6	0.6
	FT100	0.3	6.9	28.7	0.5
	DMM15	0.3	3.5	26.2	0.4
4	2D	0.2	3.5	27.8	0.5
	CARB	0.2	3.3	26.6	0.5
	LS	0.2	2.9	26.7	0.4
	B20	0.2	2.8	27.0	0.3
	FT20	0.1	2.9	26.6	0.4
	FT100	0.1	2.9	27.3	0.3
	DMM15	0.2	2.3	26.6	0.2
5	2D	0.3	6.6	16.4	1.2
	CARB	0.3	6.3	17.7	0.9
	LS	0.2	4.8	17.2	0.8
	B20	0.2	4.9	17.8	0.7
	FT20	0.2	4.8	16.1	0.8
	FT100	0.2	4.2	16.9	0.7
	DMM15	0.3	4.1	17.0	0.5

Table A-2 (continued). Average Emission Indices: Grams Emission per Kilogram Fuel					
Average Emission Rates (g emission/kg fuel)					
Mode	**Fuel**	**HC**	**CO**	**NOx**	**PM**
6	2D	1.2	18.1	9.1	2.0
	CARB	1.1	16.0	8.9	1.6
	LS	0.6	10.3	9.7	1.5
	B20	0.7	10.4	9.5	1.3
	FT20	0.7	10.6	9.5	1.5
	FT100	0.6	8.8	10.0	1.2
	DMM15	0.8	10.8	8.6	0.9
7	2D	0.1	16.8	24.8	1.0
	CARB	0.1	19.1	23.6	1.0
	LS	0.1	21.5	23.5	1.0
	B20	0.1	17.0	24.3	0.7
	FT20	0.1	19.0	23.7	0.9
	FT100	0.1	17.5	24.5	0.7
	DMM15	0.1	14.7	23.5	0.5
8	2D	0.1	6.2	27.0	0.6
	CARB	0.1	7.4	25.8	0.6
	LS	0.1	7.1	25.8	0.5
	B20	0.1	6.0	26.6	0.4
	FT20	0.1	7.1	25.6	0.5
	FT100	0.1	6.4	26.2	0.4
	DMM15	0.1	6.9	26.0	0.3
9	2D	0.2	3.8	20.2	0.7
	CARB	0.2	3.6	21.1	0.6
	LS	0.1	2.8	22.4	0.5
	B20	0.2	2.9	22.5	0.5
	FT20	0.1	2.9	21.3	0.5
	FT100	0.1	2.6	21.7	0.4
	DMM15	0.2	2.7	21.4	0.3
10	2D	4.3	43.7	5.9	1.2
	CARB	4.1	39.8	5.1	0.6
	LS	1.2	20.9	5.3	0.7
	B20	1.5	21.3	5.4	0.7
	FT20	1.5	20.2	4.6	0.7
	FT100	1.1	15.8	5.0	0.6
	DMM15	2.7	27.2	4.4	0.4

Table A-2 (continued). Average Emission Indices: Grams Emission per Kilogram Fuel					
Average Emission Rates (g emission/kg fuel)					
Mode	**Fuel**	**HC**	**CO**	**NOx**	**PM**
11	2D	2.0	19.8	6.2	1.0
	CARB	1.6	17.6	4.3	0.6
	LS	0.5	10.7	4.0	0.8
	B20	1.1	11.0	5.0	0.7
	FT20	1.0	11.4	3.9	0.8
	FT100	0.6	9.4	4.3	0.7
	DMM15	1.0	11.3	4.3	0.4
12	2D	6.9	58.8	10.7	1.7
	CARB	7.4	57.0	4.7	0.8
	LS	0.9	22.3	5.9	0.5
	B20	4.0	29.1	5.3	0.6
	FT20	1.2	22.6	5.7	0.5
	FT100	0.9	19.2	4.9	0.5
	DMM15	2.3	18.7	5.0	0.3
13	2D	11.4	64.9	5.5	2.2
	CARB	6.0	52.5	6.4	0.9
	LS	2.2	20.9	7.2	0.7
	B20	5.2	29.3	6.5	0.8
	FT20	0.6	24.0	5.9	0.6
	FT100	1.0	18.6	5.9	0.6
	DMM15	2.1	20.0	7.9	0.4
Average	2D	2.2	20.9	18.9	1.2
	CARB	1.7	19.2	17.2	0.9
	LS	0.5	11.5	17.6	0.8
	B20	1.1	12.3	17.8	0.7
	FT20	0.5	11.6	17.3	0.7
	FT100	0.4	10.0	17.6	0.7
	DMM15	0.9	10.1	16.8	0.5

APPENDIX B

INDIVIDUAL EMISSION TEST DATA SUMMARY SHEETS

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA PNGV ENGINE EMISSION RESULTS PROJECT NO. 02-5137-434

ENGINE NUMBER
ENGINE MODEL 98 MB OM 611
ENGINE 2.2 L(134. CID) I4 CYL
ENGINE CYCLE DIESEL
ENGINE SERIAL DE 22 LA

TEST 2D-1E RUN
DATE 3/ 6/98 TIME
COMPUTER PROGRAM SSDIL 1.3 -R
CELL 4 BAG CART 1
30 PPM S

DIESEL 2D EM-2549-F
HCR 1.84
C:.866 H:.134 O:.000 X:.000
ENGINE OIL

MODE	TARGET SPEED RPM	TARGET LOAD PCT	TARGET TORQUE LB-FT	MEASURED TIME SEC	MEASURED SPEED RPM	MEASURED TORQUE LB-FT	C - B FUEL LB/HR	INTAKE AIR TEMP DEG F	INTAKE AIR HUMID G/KG	INTAKE AIR BARO IN-HG	FACTORS NOx HUM	FACTORS PART. HUM	FACTORS DRY WET	FACTORS F
1	4200.	0.	118.	300.	4200.	118.	40.5	73.0	9.2	29.01	.974	1.020	.972	1.005
2	4200.	0.	79.	300.	4200.	79.	29.0	73.0	9.6	29.01	.979	1.016	.976	1.006
3	3400.	0.	111.	300.	3400.	111.	27.9	73.0	9.7	29.00	.981	1.014	.977	1.006
4	2600.	0.	166.	300.	2600.	166.	28.4	73.0	9.6	28.99	.981	1.015	.977	1.006
5	2600.	0.	111.	300.	2600.	111.	19.7	73.0	9.6	28.98	.980	1.015	.980	1.007
6	2300.	0.	54.	300.	2300.	54.	9.9	72.0	9.6	28.97	.981	1.014	.983	1.004
7	2000.	0.	229.	300.	2000.	229.	30.3	73.0	9.7	28.96	.982	1.014	.976	1.007
8	2000.	0.	189.	300.	2000.	189.	24.3	74.0	9.7	28.95	.982	1.014	.978	1.010
9	2000.	0.	111.	300.	2000.	111.	14.8	73.0	9.7	28.95	.982	1.014	.981	1.008
10	2000.	0,	26.	600.	2000.	26.	5.3	74.0	9.8	28.93	.984	1.012	.984	1.011
11	1500.	0.	33.	600.	1500.	33.	4.4	75.0	10.1	28.92	.988	1.009	.983	1.014
12	900.	0.	2.	1200.	900.	2.	1.1	73.0	9.1	28.90	.972	1.022	.983	1.008
13	765.	0.	4.	1200.	770.	4.	1.0	75.0	9.7	28.88	.981	1.014	.985	1.015

MODE	BHP FROM WORK	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2	WEIGHTED RESULTS MODE WF	POWER BHP	FUEL LB/HR	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2
1	95.0	4.00	58.4	529.3	20.65	58187.	.077	7.3	3.12	.31	4.50	40.72	1.59	4476.
2	64.0	9.46	222.0	340.7	19.64	41371.	.077	4.9	2.23	.73	17.07	26.20	1.51	3182.
3	73.0	5.72	125.1	356.5	10.88	39865.	.077	5.6	2.14	.44	9.62	27.42	.84	3067.
4	83.0	2.42	44.7	357.6	6.58	40756.	.077	6.4	2.18	.19	3.43	27.51	.51	3135.
5	55.0	2.85	58.3	145.9	10.67	28242.	.077	4.2	1.52	.22	4.49	11.23	.82	2172.
6	24.0	5.28	79.5	41.3	9.10	14110.	.077	1.8	.76	.41	6.11	3.18	.70	1085.
7	88.0	1.30	219.4	344.5	12.63	43273.	.077	6.8	2.33	.10	16.88	26.50	.97	3329.
8	73.0	.75	62.5	299.9	5.69	34840.	.077	5.6	1.87	.06	4.81	23.07	.44	2680.
9	43.0	1.02	26.9	139.0	4.77	21288.	.077	3.3	1.14	.08	2.07	10.69	.37	1638.
10	10.0	12.65	119.2	12.6	2.82	7416.	.077	.8	.41	.97	9.17	.97	.22	570.
11	10.0	4.25	40.0	9.8	1.73	6183.	.077	.8	.33	.33	3.08	.76	.13	476.
12	.0	2.84	27.2	3.4	.67	1504.	.077	.0	.08	.22	2.09	.26	.05	116.
13	1.0	2.27	20.8	3.8	.69	1383.	.077	.1	.08	.17	1.60	.29	.05	106.
							TOTAL	47.6	18.2	4.2	84.9	198.8	8.2	26032.

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA PNGV ENGINE EMISSION RESULTS PROJECT NO. 02-5137-434

ENGINE NUMBER	TEST 2D-2E RUN	DIESEL 2D EM-2549-F
ENGINE MODEL 98 MB OM 611	DATE 3/19/98 TIME	HCR 1.84
ENGINE 2.2 L(134. CID) I4 CYL	COMPUTER PROGRAM SSDIL 1.3 -R	C:.866 H:.134 O:.000 X:.000
ENGINE CYCLE DIESEL	CELL 4 BAG CART 1	ENGINE OIL
ENGINE SERIAL DE 22 LA	30 PPM S	

MODE	TARGET SPEED RPM	TARGET LOAD PCT	TARGET TORQUE LB-FT	MEASURED TIME SEC	MEASURED SPEED RPM	MEASURED TORQUE LB-FT	C - B FUEL LB/HR	INTAKE AIR TEMP DEG F	INTAKE AIR HUMID G/KG	INTAKE AIR BARO IN-HG	FACTORS NOx HUM	FACTORS PART. HUM	FACTORS DRY WET	FACTORS F
1	4200.	0.	117.	300.	4200.	117.	40.4	73.0	10.0	29.06	.987	1.009	.976	1.005
2	4200.	0.	79.	300.	4200.	79.	29.6	74.0	10.0	29.06	.987	1.009	.981	1.008
3	3400.	0.	111.	300.	3400.	111.	27.7	74.0	9.2	29.05	.973	1.021	.983	1.007
4	2600.	0.	167.	300.	2600.	167.	28.5	73.0	8.9	29.06	.967	1.025	.982	1.004
5	2600.	0.	111.	300.	2600.	111.	19.8	73.0	9.0	29.05	.970	1.023	.985	1.004
6	2300.	0.	53.	300.	2300.	53.	9.8	73.0	9.2	29.05	.973	1.021	.989	1.004
7	2000.	0.	229.	300.	2000.	229.	30.7	74.0	9.2	29.05	.974	1.020	.982	1.007
8	2000.	0.	190.	300.	2000.	190.	24.6	74.0	9.2	29.05	.973	1.021	.984	1.007
9	2000.	0.	111.	300.	2000.	111.	14.9	73.0	9.1	29.05	.971	1.022	.986	1.004
10	2000.	0.	25.	600.	2000.	25.	5.4	72.0	9.3	29.05	.976	1.019	.990	1.002
11	1500.	0.	32.	600.	1500.	32.	4.2	73.0	9.3	29.05	.976	1.019	.990	1.005
12	900.	0.	2.	1200.	900.	2.	1.0	73.0	9.1	29.05	.971	1.022	.988	1.004
13	765.	0.	4.	1200.	765.	4.	1.0	72.0	9.0	29.04	.970	1.023	.992	1.002

MODE	BHP FROM WORK	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2	WEIGHTED RESULTS MODE WF	POWER BHP	FUEL LB/HR	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2
1	94.0	4.30	54.7	536.7	19.78	58055.	.077	7.2	3.11	.33	4.20	41.28	1.52	4466.
2	64.0	8.94	226.4	355.3	19.51	42241.	.077	4.9	2.28	.69	17.42	27.33	1.50	3249.
3	72.0	5.01	125.1	360.5	10.39	39574.	.077	5.5	2.13	.39	9.63	27.73	.80	3044.
4	83.0	2.32	42.9	360.5	6.60	40940.	.077	6.4	2.19	.18	3.30	27.73	.51	3149.
5	55.0	2.99	59.8	148.5	10.88	28424.	.077	4.2	1.53	.23	4.60	11.42	.84	2186.
6	23.0	5.16	81.8	39.7	8.92	14001.	.077	1.8	.76	.40	6.29	3.05	.69	1077.
7	88.0	1.54	241.0	344.4	14.59	43796.	.077	6.8	2.36	.12	18.54	26.49	1.12	3369.
8	73.0	1.33	74.4	301.1	6.53	35269.	.077	5.6	1.89	.10	5.72	23.16	.50	2713.
9	43.0	1.47	26.1	138.6	4.68	21408.	.077	3.3	1.15	.11	2.01	10.66	.36	1647.
10	10.0	11.66	113.6	12.2	2.30	7566.	.077	.8	.42	.90	8.74	.94	.18	582.
11	9.0	5.36	48.1	7.2	1.66	6021.	.077	.7	.33	.41	3.70	.55	.13	463.
12	.0	5.26	29.5	1.8	.94	1392.	.077	.0	.08	.40	2.27	.14	.07	107.
13	1.0	6.34	34.4	1.1	1.09	1375.	.077	.1	.08	.49	2.65	.09	.08	106.
							TOTAL	47.3	18.3	4.7	89.1	200.6	8.3	26159.

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA PNGV ENGINE EMISSION RESULTS PROJECT NO. 02-5137-434

ENGINE NUMBER
ENGINE MODEL 98 MB OM 611
ENGINE 2.2 L(134. CID) I4 CYL
ENGINE CYCLE DIESEL
ENGINE SERIAL DE 22 LA

TEST 2D-3E RUN
DATE 4/ 1/98 TIME
COMPUTER PROGRAM SSDIL 1.3 -R
CELL 4 BAG CART 1

DIESEL 2D EM-2549-F
HCR 1.84
C:.866 H:.134 O:.000 X:.000
ENGINE OIL
DENS. 6.935

MODE	TARGET SPEED RPM	TARGET LOAD PCT	TARGET TORQUE LB-FT	MEASURED TIME SEC	MEASURED SPEED RPM	MEASURED TORQUE LB-FT	C - B FUEL LB/HR	INTAKE AIR TEMP DEG F	INTAKE AIR HUMID G/KG	INTAKE AIR BARO IN-HG	FACTORS NOx HUM	FACTORS PART. HUM	FACTORS DRY WET	FACTORS F
1	4200.	0.	117.	300.	4200.	117.	40.3	73.0	9.2	29.13	.973	1.020	.976	1.002
2	4200.	0.	79.	300.	4200.	79.	29.6	73.0	9.2	29.13	.973	1.021	.980	1.003
3	3400.	0.	111.	300.	3400.	111.	28.1	73.0	9.0	29.13	.970	1.023	.981	1.002
4	2600.	0.	166.	300.	2600.	166.	28.6	73.0	8.8	29.13	.966	1.026	.980	1.002
5	2600.	0.	111.	300.	2600.	111.	20.5	73.0	8.6	29.13	.963	1.029	.983	1.002
6	2300.	0.	52.	300.	2300.	52.	9.5	74.0	8.6	29.12	.963	1.029	.986	1.005
7	2000.	0.	228.	300.	2000.	228.	30.4	73.0	8.5	29.12	.961	1.031	.978	1.002
8	2000.	0.	188.	300.	2000.	188.	24.5	73.0	8.4	29.11	.959	1.032	.982	1.002
9	2000.	0.	111.	300.	2000.	111.	15.0	73.0	8.3	29.10	.958	1.033	.985	1.002
10	2000.	0.	25.	600.	2000.	25.	5.0	72.0	8.4	29.09	.959	1.032	.990	1.000
11	1500.	0.	34.	600.	1500.	34.	4.4	72.0	8.1	29.09	.955	1.035	.990	1.000
12	900.	0.	2.	1200.	900.	2.	1.0	73.0	8.2	29.08	.956	1.035	.990	1.003
13	765.	0.	1.	1200.	768.	1.	.9	76.0	8.7	29.06	.965	1.027	.992	1.012

MODE	BHP FROM WORK	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2	WEIGHTED MODE WF	WEIGHTED POWER BHP	WEIGHTED FUEL LB/HR	WEIGHTED GRAMS/HOUR HC	WEIGHTED GRAMS/HOUR CO	WEIGHTED GRAMS/HOUR NOx	WEIGHTED GRAMS/HOUR PART	WEIGHTED GRAMS/HOUR CO2
1	94.0	4.38	60.4	543.3	20.93	57870.	.077	7.2	3.10	.34	4.65	41.79	1.61	4452.
2	64.0	8.84	217.5	361.9	19.73	42265.	.077	4.9	2.28	.68	16.73	27.84	1.52	3251.
3	73.0	5.20	124.4	375.2	10.23	40162.	.077	5.6	2.16	.40	9.57	28.86	.79	3089.
4	83.0	2.27	47.0	365.1	6.81	41074.	.077	6.4	2.20	.17	3.61	28.08	.52	3160.
5	56.0	2.94	61.4	154.9	10.67	29385.	.077	4.3	1.58	.23	4.72	11.92	.82	2260.
6	23.0	5.30	79.7	39.8	8.71	13538.	.077	1.8	.73	.41	6.13	3.06	.67	1041.
7	87.0	1.57	240.4	341.9	14.02	43345.	.077	6.7	2.34	.12	18.49	26.30	1.08	3334.
8	72.0	.80	70.1	300.8	6.19	35145.	.077	5.5	1.88	.06	5.40	23.14	.48	2703.
9	43.0	.80	25.1	133.6	4.86	21483.	.077	3.3	1.15	.06	1.93	10.28	.37	1653.
10	10.0	6.48	82.1	17.6	3.29	7113.	.077	.8	.39	.50	6.32	1.36	.25	547.
11	10.0	2.28	28.3	19.8	2.51	6287.	.077	.8	.34	.18	2.17	1.52	.19	484.
12	1.0	1.56	25.9	9.8	.77	1348.	.077	.1	.07	.12	1.99	.75	.06	104.
13	.0	6.20	30.0	2.4	1.10	1206.	.077	.0	.07	.48	2.31	.19	.08	93.
							TOTAL	47.4	18.3	3.7	84.0	205.1	8.4	26171.

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA PNGV ENGINE EMISSION RESULTS PROJECT NO. 02-5137-434

ENGINE NUMBER
ENGINE MODEL 98 MB OM 611
ENGINE 2.2 L(134. CID) I4 CYL
ENGINE CYCLE DIESEL
ENGINE SERIAL DE 22 LA

TEST LS-1E RUN
DATE 3/11/98 TIME
COMPUTER PROGRAM SSDIL 1.3 -R
CELL 4 BAG CART 1

DIESEL LS EM-2539-F
HCR 2.00
C:.856 H:.144 O:.000 X:.000
ENGINE OIL
DENS. 6.768

MODE	TARGET SPEED RPM	TARGET LOAD PCT	TARGET TORQUE LB-FT	MEASURED TIME SEC	MEASURED SPEED RPM	MEASURED TORQUE LB-FT	C - B FUEL LB/HR	INTAKE AIR TEMP DEG F	INTAKE AIR HUMID G/KG	INTAKE AIR BARO IN-HG	FACTORS NOx HUM	FACTORS PART. HUM	FACTORS DRY WET	FACTORS F
1	4200.	0.	118.	300.	4200.	118.	40.1	76.0	9.1	29.59	.971	1.022	.979	1.000
2	4200.	0.	78.	300.	4200.	78.	28.1	75.0	9.4	29.59	.976	1.018	.984	.997
3	3400.	0.	112.	300.	3400.	112.	27.9	75.0	9.5	29.58	.978	1.017	.985	.998
4	2600.	0.	167.	300.	2600.	167.	28.2	75.0	9.5	29.57	.978	1.017	.984	.998
5	2600.	0.	111.	300.	2600.	111.	20.0	75.0	9.4	29.56	.977	1.017	.987	.998
6	2300.	0.	54.	300.	2300.	54.	9.9	76.0	9.1	29.55	.971	1.022	.987	1.001
7	2000.	0.	224.	300.	2000.	224.	29.3	76.0	9.2	29.55	.973	1.021	.981	1.001
8	2000.	0.	190.	300.	2000.	190.	24.3	76.0	9.0	29.54	.971	1.023	.986	1.001
9	2000.	0.	110.	300.	2000.	110.	14.6	75.0	9.1	29.53	.971	1.022	.989	.998
10	2000.	0.	25.	600.	2000.	25.	5.1	76.0	8.9	29.52	.968	1.024	.993	1.001
11	1500.	0.	33.	600.	1500.	33.	5.1	75.0	8.5	29.52	.961	1.030	.992	.998
12	900.	0.	2.	1200.	900.	2.	1.1	82.0	8.9	29.51	.967	1.025	.994	1.018
13	765.	0.	2.	1200.	765.	2.	.9	84.0	8.9	29.51	.968	1.024	.994	1.024

MODE	BHP FROM WORK	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2	WEIGHTED RESULTS MODE WF	POWER BHP	FUEL LB/HR	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2
1	95.0	3.37	55.8	510.3	17.28	56951.	.077	7.3	3.09	.26	4.30	39.26	1.33	4381.
2	63.0	6.86	185.6	339.4	14.72	39634.	.077	4.8	2.16	.53	14.28	26.11	1.13	3049.
3	73.0	3.58	97.0	364.8	8.38	39457.	.077	5.6	2.14	.28	7.46	28.06	.64	3035.
4	83.0	1.78	38.6	347.1	5.12	40083.	.077	6.4	2.17	.14	2.97	26.70	.39	3083.
5	55.0	1.83	44.3	158.7	7.45	28302.	.077	4.2	1.53	.14	3.41	12.21	.57	2177.
6	24.0	1.77	45.0	45.2	6.62	13978.	.077	1.8	.76	.14	3.46	3.48	.51	1075.
7	86.0	.57	273.8	317.5	12.48	41186.	.077	6.6	2.25	.04	21.06	24.42	.96	3168.
8	73.0	.50	75.8	292.1	5.03	34415.	.077	5.6	1.87	.04	5.83	22.47	.39	2647.
9	42.0	.00	19.0	148.9	3.22	20783.	.077	3.2	1.13	.00	1.46	11.45	.25	1599.
10	9.0	2.13	49.5	13.4	1.72	7225.	.077	.7	.40	.16	3.80	1.03	.13	556.
11	9.0	1.32	24.1	7.3	2.02	7201.	.077	.7	.39	.10	1.86	.56	.16	554.
12	1.0	.37	11.5	3.1	.28	1557.	.077	.1	.09	.03	.88	.24	.02	120.
13	.0	1.23	8.8	3.4	.29	1307.	.077	.0	.07	.09	.67	.26	.02	101.
							TOTAL	47.2	18.0	1.9	71.4	196.3	6.5	25544.

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA PNGV ENGINE EMISSION RESULTS PROJECT NO. 02-5137-434

ENGINE NUMBER
ENGINE MODEL 98 MB OM 611
ENGINE .0 L(2. CID) I4 CYL
ENGINE CYCLE DIESEL
ENGINE SERIAL DE 22 LA

TEST LS-2E RUN
DATE 3/16/98 TIME
COMPUTER PROGRAM SSDIL 1.3 -R
CELL 4 BAG CART 1

DIESEL LS EM-2539-F
HCR 2.05
C:.853 H:.147 O:.000 X:.000
ENGINE OIL
DENS. 6.726

MODE	TARGET SPEED RPM	TARGET LOAD PCT	TARGET TORQUE LB-FT	MEASURED TIME SEC	MEASURED SPEED RPM	MEASURED TORQUE LB-FT	C - B FUEL LB/HR	INTAKE AIR TEMP DEG F	INTAKE AIR HUMID G/KG	INTAKE AIR BARO IN-HG	FACTORS NOx HUM	FACTORS PART. HUM	FACTORS DRY WET	FACTORS F
1	4200.	0.	118.	300.	4200.	118.	39.6	74.0	10.0	28.78	.987	1.010	.970	1.015
2	4200.	0.	78.	300.	4200.	78.	29.5	73.0	10.0	28.78	.987	1.010	.975	1.012
3	3400.	0.	111.	300.	3400.	111.	28.6	74.0	10.1	28.77	.989	1.008	.975	1.015
4	2600.	0.	167.	300.	2600.	167.	29.8	74.0	9.4	28.78	.977	1.017	.974	1.014
5	2600.	0.	112.	300.	2600.	112.	19.9	73.0	8.9	28.77	.968	1.024	.980	1.011
6	2300.	0.	53.	300.	2300.	53.	9.8	73.0	9.2	28.76	.972	1.021	.983	1.011
7	2000.	0.	224.	300.	2000.	224.	28.9	74.0	9.3	28.76	.975	1.019	.976	1.014
8	2000.	0.	190.	300.	2000.	190.	24.6	74.0	9.3	28.76	.975	1.019	.978	1.015
9	2000.	0.	111.	300.	2000.	111.	14.8	73.0	9.3	28.76	.975	1.019	.982	1.012
10	2000.	0.	25.	600.	2000.	25.	5.2	74.0	9.4	28.76	.977	1.017	.986	1.015
11	1500.	0.	34.	600.	1500.	34.	4.4	72.0	9.3	28.76	.975	1.019	.985	1.009
12	900.	0.	2.	1200.	900.	2.	1.1	76.0	9.6	28.76	.981	1.014	.987	1.021
13	765.	0.	4.	1200.	765.	4.	1.1	78.0	8.9	28.77	.968	1.024	.994	1.025

MODE	BHP FROM WORK	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2	WEIGHTED RESULTS MODE WF	POWER BHP	FUEL LB/HR	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2
1	96.0	4.25	54.1	510.4	16.52	56024.	.077	7.4	3.05	.33	4.16	39.26	1.27	4310.
2	63.0	7.77	197.5	330.6	14.92	41475.	.077	4.8	2.27	.60	15.19	25.43	1.15	3190.
3	72.0	4.50	102.6	354.7	8.16	40293.	.077	5.5	2.20	.35	7.89	27.28	.63	3099.
4	84.0	2.19	38.5	350.0	5.14	42115.	.077	6.5	2.29	.17	2.96	26.92	.40	3240.
5	56.0	2.14	43.8	158.9	7.40	28181.	.077	4.3	1.53	.16	3.37	12.22	.57	2168.
6	24.0	2.83	46.5	43.2	6.48	13870.	.077	1.8	.76	.22	3.57	3.32	.50	1067.
7	86.0	1.65	297.4	312.4	13.53	40486.	.077	6.6	2.22	.13	22.88	24.03	1.04	3114.
8	73.0	.65	91.5	284.9	5.74	34701.	.077	5.6	1.89	.05	7.04	21.92	.44	2669.
9	42.0	.25	18.2	153.0	3.19	20910.	.077	3.2	1.14	.02	1.40	11.77	.25	1608.
10	9.0	3.18	49.1	11.7	1.67	7272.	.077	.7	.40	.24	3.78	.90	.13	559.
11	10.0	.00	21.0	9.0	1.45	6172.	.077	.8	.34	.00	1.62	.69	.11	475.
12	.0	.00	11.2	2.5	.24	1556.	.077	.0	.09	.00	.86	.19	.02	120.
13	1.0	.38	8.6	3.6	.28	1521.	.077	.1	.08	.03	.66	.28	.02	117.
							TOTAL	47.4	18.2	2.3	75.4	194.2	6.5	25737.

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA PNGV ENGINE EMISSION RESULTS PROJECT NO. 02-5137-434

ENGINE NUMBER
ENGINE MODEL 98 MB OM 611
ENGINE .0 L(2. CID) I4 CYL
ENGINE CYCLE DIESEL
ENGINE SERIAL DE 22 LA

TEST LS-3E RUN
DATE 3/18/98 TIME
COMPUTER PROGRAM SSDIL 1.3 -R
CELL 4 BAG CART 1

DIESEL LS EM-2539-F
HCR 2.05
C:.853 H:.147 O:.000 X:.000
ENGINE OIL
DENS. 6.726

MODE	TARGET SPEED RPM	TARGET LOAD PCT	TARGET TORQUE LB-FT	MEASURED TIME SEC	MEASURED SPEED RPM	MEASURED TORQUE LB-FT	C - B FUEL LB/HR	INTAKE AIR TEMP DEG F	INTAKE AIR HUMID G/KG	INTAKE AIR BARO IN-HG	FACTORS NOx HUM	FACTORS PART. HUM	FACTORS DRY WET	FACTORS F
1	4200.	0.	118.	300.	4200.	118.	41.0	74.0	9.9	28.88	.986	1.011	.967	1.012
2	4200.	0.	79.	300.	4200.	79.	30.2	74.0	9.3	28.88	.975	1.019	.970	1.012
3	3400.	0.	111.	300.	3400.	111.	27.9	74.0	8.9	28.87	.968	1.025	.971	1.011
4	2600.	0.	167.	300.	2600.	167.	28.6	75.0	8.6	28.87	.962	1.029	.972	1.014
5	2600.	0.	111.	300.	2600.	111.	19.8	74.0	8.1	28.86	.955	1.036	.974	1.011
6	2300.	0.	53.	300.	2300.	53.	9.9	73.0	8.2	28.86	.957	1.034	.979	1.008
7	2000.	0.	224.	300.	2000.	224.	30.0	74.0	8.4	28.85	.959	1.032	.972	1.011
8	2000.	0.	189.	300.	2000.	189.	25.0	74.0	8.4	28.85	.959	1.032	.973	1.011
9	2000.	0.	112.	300.	2000.	112.	15.2	74.0	8.4	28.84	.959	1.032	.978	1.011
10	2000.	0.	25.	600.	2000.	25.	5.5	73.0	8.6	28.84	.962	1.029	.981	1.009
11	1500.	0.	33.	600.	1500.	33.	4.4	75.0	8.7	28.83	.965	1.027	.980	1.015
12	900.	0.	1.	1200.	900.	1.	1.1	80.0	9.7	28.83	.982	1.014	.983	1.030
13	765.	0.	4.	1200.	765.	4.	1.0	81.0	9.3	28.83	.974	1.020	.982	1.033

MODE	BHP FROM WORK	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2	WEIGHTED RESULTS MODE WF	POWER BHP	FUEL LB/HR	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2
1	95.0	4.29	55.1	513.8	16.49	57982.	.077	7.3	3.15	.33	4.24	39.52	1.27	4460.
2	64.0	6.51	178.3	341.5	14.47	42481.	.077	4.9	2.32	.50	13.71	26.27	1.11	3268.
3	72.0	3.93	96.4	356.1	8.43	39411.	.077	5.5	2.15	.30	7.42	27.39	.65	3032.
4	83.0	2.09	37.0	353.2	5.16	40492.	.077	6.4	2.20	.16	2.85	27.17	.40	3115.
5	55.0	1.84	43.1	148.0	7.69	27920.	.077	4.2	1.52	.14	3.31	11.38	.59	2148.
6	23.0	2.85	46.5	42.6	6.90	13974.	.077	1.8	.76	.22	3.57	3.28	.53	1075.
7	86.0	1.57	289.9	312.5	13.86	42064.	.077	6.6	2.31	.12	22.30	24.04	1.07	3236.
8	73.0	1.08	72.6	290.9	5.11	35263.	.077	5.6	1.92	.08	5.59	22.38	.39	2713.
9	43.0	.78	19.1	151.5	3.54	21466.	.077	3.3	1.17	.06	1.47	11.66	.27	1651.
10	10.0	3.35	51.5	13.1	1.79	7655.	.077	.8	.42	.26	3.96	1.01	.14	589.
11	10.0	1.81	22.7	8.6	1.60	6207.	.077	.8	.34	.14	1.75	.66	.12	477.
12	.0	.93	10.7	3.3	.25	1504.	.077	.0	.08	.07	.82	.25	.02	116.
13	1.0	1.27	10.9	2.8	.40	1357.	.077	.1	.07	.10	.84	.21	.03	104.
							TOTAL	47.3	18.4	2.5	71.8	195.2	6.6	25983.

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA PNGV ENGINE EMISSION RESULTS PROJECT NO. 02-5137-434

ENGINE NUMBER
ENGINE MODEL 98 MB OM 611
ENGINE 2.2 L(134. CID) I4 CYL
ENGINE CYCLE DIESEL
ENGINE SERIAL DE 22 LA

TEST CARB-1E RUN
DATE 3/24/98 TIME
COMPUTER PROGRAM SSDIL 1.3 -R
CELL 4 BAG CART 2

DIESEL CARB EM-2540-F
HCR 1.92
C:.861 H:.139 O:.000 X:.000
ENGINE OIL
DENS. 6.935

MODE	TARGET SPEED RPM	TARGET LOAD PCT	TARGET TORQUE LB-FT	MEASURED TIME SEC	MEASURED SPEED RPM	MEASURED TORQUE LB-FT	C - B FUEL LB/HR	INTAKE AIR TEMP DEG F	INTAKE AIR HUMID G/KG	INTAKE AIR BARO IN-HG	FACTORS NOx HUM	FACTORS PART. HUM	FACTORS DRY WET	FACTORS F
1	4200.	0.	118.	300.	4200.	118.	41.1	73.0	9.3	29.13	.975	1.019	.967	1.003
2	4200.	0.	78.	300.	4200.	78.	29.2	73.0	8.6	29.13	.963	1.029	.972	1.002
3	3400.	0.	111.	300.	3400.	111.	27.7	74.0	8.5	29.13	.962	1.030	.972	1.005
4	2600.	0.	167.	300.	2600.	167.	28.2	73.0	8.7	29.13	.965	1.027	.972	1.002
5	2600.	0.	111.	300.	2600.	111.	20.0	73.0	8.8	29.13	.966	1.026	.975	1.002
6	2300.	0.	53.	300.	2300.	53.	9.7	74.0	9.0	29.13	.969	1.024	.979	1.005
7	2000.	0.	228.	300.	2000.	228.	30.1	73.0	9.2	29.12	.973	1.021	.970	1.003
8	2000.	0.	189.	300.	2000.	189.	23.4	74.0	9.0	29.12	.970	1.023	.974	1.005
9	2000.	0.	110.	300.	2000.	110.	14.8	74.0	9.2	29.12	.973	1.021	.977	1.006
10	2000.	0.	25.	600.	2000.	25.	5.3	71.0	9.0	29.12	.969	1.024	.981	.997
11	1500.	0.	33.	600.	1500.	33.	4.5	72.0	8.4	29.11	.959	1.032	.982	.999
12	900.	0.	2.	1200.	900.	2.	1.1	76.0	9.0	29.10	.971	1.023	.981	1.011
13	765.	0.	4.	1200.	765.	4.	1.0	77.0	9.6	29.09	.981	1.014	.982	1.015

MODE	BHP FROM WORK	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2	WEIGHTED RESULTS MODE WF	POWER BHP	FUEL LB/HR	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2
1	95.0	5.15	60.4	507.9	19.62	58617.	.077	7.3	3.16	.40	4.64	39.07	1.51	4509.
2	63.0	10.82	202.4	332.5	17.02	41444.	.077	4.8	2.25	.83	15.57	25.57	1.31	3188.
3	72.0	6.13	111.1	347.7	9.58	39409.	.077	5.5	2.13	.47	8.55	26.75	.74	3031.
4	84.0	2.55	43.0	345.6	6.86	40216.	.077	6.5	2.17	.20	3.31	26.59	.53	3094.
5	56.0	2.71	56.6	153.7	8.91	28478.	.077	4.3	1.54	.21	4.35	11.83	.69	2191.
6	23.0	4.75	72.5	38.9	7.25	13758.	.077	1.8	.75	.37	5.58	2.99	.56	1058.
7	87.0	1.36	256.4	327.0	13.56	42677.	.077	6.7	2.32	.10	19.72	25.15	1.04	3283.
8	72.0	1.08	68.8	289.2	5.86	33402.	.077	5.5	1.80	.08	5.29	22.25	.45	2569.
9	42.0	1.09	25.1	135.2	4.25	21200.	.077	3.2	1.14	.08	1.93	10.40	.33	1631.
10	10.0	9.21	98.6	11.6	1.39	7446.	.077	.8	.41	.71	7.59	.89	.11	573.
11	10.0	2.62	34.6	9.0	1.37	6357.	.077	.8	.35	.20	2.66	.69	.11	489.
12	1.0	3.28	27.0	2.8	.46	1482.	.077	.1	.08	.25	2.08	.22	.04	114.
13	1.0	2.99	28.2	2.1	.43	1445.	.077	.1	.08	.23	2.17	.16	.03	111.
							TOTAL	47.4	18.2	4.1	83.4	192.6	7.4	25841.

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA PNGV ENGINE EMISSION RESULTS PROJECT NO. 02-5137-434

ENGINE NUMBER	TEST CARB-2E RUN	DIESEL CARB EM-2540-F
ENGINE MODEL 98 MB OM 611	DATE 3/26/98 TIME	HCR 1.92
ENGINE 2.2 L(134. CID) I4 CYL	COMPUTER PROGRAM SSDIL 1.3 -R	C:.861 H:.139 O:.000 X:.000
ENGINE CYCLE DIESEL	CELL 4 BAG CART 1	ENGINE OIL
ENGINE SERIAL DE 22 LA		DENS. 6.935

MODE	TARGET SPEED RPM	TARGET LOAD PCT	TARGET TORQUE LB-FT	MEASURED TIME SEC	MEASURED SPEED RPM	MEASURED TORQUE LB-FT	C - B FUEL LB/HR	INTAKE AIR TEMP DEG F	INTAKE AIR HUMID G/KG	INTAKE AIR BARO IN-HG	FACTORS NOx HUM	FACTORS PART. HUM	FACTORS DRY WET	FACTORS F
1	4200.	0.	117.	300.	4200.	117.	40.4	73.0	9.3	29.19	.975	1.019	.967	1.001
2	4200.	0.	79.	300.	4200.	79.	30.0	73.0	9.0	29.18	.970	1.023	.971	1.001
3	3400.	0.	111.	300.	3400.	111.	27.8	73.0	8.8	29.18	.966	1.026	.971	1.001
4	2600.	0.	167.	300.	2600.	167.	28.9	74.0	8.5	29.17	.961	1.031	.972	1.004
5	2600.	0.	111.	300.	2600.	111.	20.1	73.0	8.6	29.17	.963	1.029	.975	1.001
6	2300.	0.	53.	300.	2300.	53.	9.6	74.0	8.6	29.16	.963	1.029	.979	1.004
7	2000.	0.	226.	300.	2000.	226.	29.8	74.0	9.0	29.14	.970	1.023	.971	1.005
8	2000.	0.	189.	300.	2000.	189.	24.8	74.0	8.8	29.13	.967	1.026	.974	1.005
9	2000.	0.	112.	300.	2000.	112.	15.2	74.0	8.4	29.12	.959	1.032	.977	1.005
10	2000.	0.	26.	600.	2000.	26.	5.5	74.0	8.1	29.11	.955	1.035	.979	1.005
11	2000.	0.	33.	600.	2000.	33.	4.5	75.0	8.2	29.10	.956	1.035	.981	1.008
12	900.	0.	1.	1200.	900.	1.	1.0	81.0	9.2	29.09	.973	1.021	.982	1.026
13	765.	0.	3.	1200.	765.	3.	1.0	83.0	9.2	29.08	.974	1.020	.983	1.032

MODE	BHP FROM WORK	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2	WEIGHTED RESULTS MODE WF	POWER BHP	FUEL LB/HR	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2
1	94.0	6.20	59.7	493.8	19.34	57752.	.077	7.2	3.11	.48	4.59	37.99	1.49	4442.
2	64.0	10.47	199.2	346.9	17.03	42612.	.077	4.9	2.31	.81	15.32	26.68	1.31	3278.
3	72.0	6.35	112.5	346.4	9.36	39557.	.077	5.5	2.14	.49	8.65	26.65	.72	3043.
4	84.0	2.96	43.0	349.4	6.38	41207.	.077	6.5	2.22	.23	3.30	26.88	.49	3170.
5	55.0	3.64	57.6	167.0	7.78	28659.	.077	4.2	1.55	.28	4.43	12.84	.60	2205.
6	23.0	5.27	70.6	40.2	3.68	13558.	.077	1.8	.74	.41	5.43	3.09	.28	1043.
7	87.0	1.89	269.3	320.0	14.21	42131.	.077	6.7	2.29	.15	20.71	24.61	1.09	3241.
8	72.0	1.59	87.3	283.4	6.48	35290.	.077	5.5	1.91	.12	6.71	21.80	.50	2715.
9	44.0	1.64	23.4	156.2	3.71	21672.	.077	3.4	1.17	.13	1.80	12.02	.29	1667.
10	10.0	9.71	92.0	14.5	1.46	7721.	.077	.8	.42	.75	7.08	1.11	.11	594.
11	10.0	4.09	38.1	8.2	1.34	6306.	.077	.8	.34	.31	2.93	.63	.10	485.
12	.0	4.96	27.4	2.1	.37	1418.	.077	.0	.08	.38	2.10	.16	.03	109.
13	1.0	2.58	16.0	4.8	.38	1354.	.077	.1	.07	.20	1.23	.37	.03	104.
							TOTAL	47.4	18.3	4.7	84.3	194.8	7.0	26095.

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH
EPA PNGV ENGINE EMISSION RESULTS PROJECT NO. 02-5137-434

ENGINE NUMBER
ENGINE MODEL 98 MB OM 611
ENGINE 2.2 L(134. CID) I4 CYL
ENGINE CYCLE DIESEL
ENGINE SERIAL DE 22 LA

TEST CARB-3E RUN
DATE 3/31/98 TIME
COMPUTER PROGRAM SSDIL 1.3 -R
CELL 4 BAG CART 1

DIESEL CARB EM-2540-F
HCR 1.92
C:.861 H:.139 O:.000 X:.000
ENGINE OIL
DENS. 6.935

MODE	TARGET SPEED RPM	TARGET LOAD PCT	TARGET TORQUE LB-FT	MEASURED TIME SEC	MEASURED SPEED RPM	MEASURED TORQUE LB-FT	C - B FUEL LB/HR	INTAKE AIR TEMP DEG F	INTAKE AIR HUMID G/KG	INTAKE AIR BARO IN-HG	FACTORS NOx HUM	FACTORS PART. HUM	FACTORS DRY WET	FACTORS F
1	4200.	0.	118.	300.	4200.	118.	41.0	73.0	9.0	29.06	.970	1.023	.978	1.004
2	4200.	0.	79.	300.	4200.	79.	30.1	73.0	8.8	29.06	.967	1.026	.981	1.004
3	3400.	0.	112.	300.	3400.	112.	28.8	73.0	8.6	29.05	.964	1.028	.983	1.004
4	2600.	0.	166.	300.	2600.	166.	28.5	73.0	8.8	29.05	.967	1.026	.983	1.004
5	2600.	0.	111.	300.	2600.	111.	19.8	73.0	8.8	29.05	.967	1.026	.986	1.004
6	2300.	0.	53.	300.	2300.	53.	9.8	73.0	9.0	29.05	.970	1.023	.986	1.004
7	2000.	0.	227.	300.	2000.	227.	30.6	73.0	9.0	29.04	.970	1.023	.982	1.004
8	2000.	0.	189.	300.	2000.	189.	24.7	73.0	8.9	29.04	.968	1.025	.984	1.004
9	2000.	0.	110.	300.	2000.	110.	15.0	73.0	8.5	29.03	.962	1.030	.987	1.004
10	2000.	0.	25.	600.	2000.	25.	5.5	72.0	8.4	29.02	.959	1.032	.991	1.001
11	1500.	0.	34.	600.	1500.	34.	4.5	72.0	8.4	29.01	.959	1.032	.992	1.002
12	900.	0.	3.	1200.	900.	3.	1.1	73.0	8.5	29.01	.962	1.030	.994	1.005
13	765.	0.	2.	1200.	762.	2.	.9	74.0	8.8	28.99	.967	1.025	.993	1.008

MODE	BHP FROM WORK	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2	WEIGHTED RESULTS MODE WF	POWER BHP	FUEL LB/HR	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2
1	95.0	3.84	59.7	507.5	18.94	58499.	.077	7.3	3.15	.30	4.59	39.04	1.46	4500.
2	63.0	8.41	206.7	337.7	16.36	42719.	.077	4.8	2.32	.65	15.90	25.97	1.26	3286.
3	73.0	4.55	107.9	349.1	8.91	40977.	.077	5.6	2.21	.35	8.30	26.85	.69	3152.
4	83.0	2.37	42.3	339.1	6.12	40763.	.077	6.4	2.20	.18	3.26	26.08	.47	3136.
5	56.0	2.93	57.4	161.2	8.42	28189.	.077	4.3	1.52	.23	4.41	12.40	.65	2168.
6	23.0	4.78	69.0	39.0	7.26	13867.	.077	1.8	.75	.37	5.31	3.00	.56	1067.
7	87.0	1.99	260.3	324.2	13.67	43296.	.077	6.7	2.35	.15	20.02	24.93	1.05	3330.
8	73.0	1.38	90.8	282.7	6.45	35139.	.077	5.6	1.90	.11	6.99	21.75	.50	2703.
9	42.0	1.31	25.5	139.6	3.67	21457.	.077	3.2	1.16	.10	1.96	10.74	.28	1651.
10	10.0	11.19	104.4	11.6	1.33	7690.	.077	.8	.42	.86	8.03	.89	.10	592.
11	10.0	3.26	35.5	9.0	1.08	6413.	.077	.8	.35	.25	2.73	.69	.08	493.
12	1.0	2.30	28.3	2.0	.29	1550.	.077	.1	.09	.18	2.18	.15	.02	119.
13	.0	2.32	24.6	1.7	.37	1222.	.077	.0	.07	.18	1.89	.13	.03	94.
							TOTAL	47.4	18.5	3.9	85.6	192.6	7.1	26291.

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA PNGV ENGINE EMISSION RESULTS PROJECT NO. 02-5137-434

ENGINE NUMBER
ENGINE MODEL 98 MB OM 611
ENGINE 2.2 L(134. CID) I4 CYL
ENGINE CYCLE DIESEL
ENGINE SERIAL DE 22 LA

TEST B20-1E RUN
DATE 3/12/98 TIME
COMPUTER PROGRAM SSDIL 1.3 -R
CELL 4 BAG CART 1

DIESEL B20 EM-2565-F
HCR 1.99
C:.837 H:.140 O:.023 X:.000
ENGINE OIL
DENS. 6.893

MODE	TARGET SPEED RPM	TARGET LOAD PCT	TARGET TORQUE LB-FT	MEASURED TIME SEC	MEASURED SPEED RPM	MEASURED TORQUE LB-FT	C - B FUEL LB/HR	INTAKE AIR TEMP DEG F	INTAKE AIR HUMID G/KG	INTAKE AIR BARO IN-HG	FACTORS NOx HUM	FACTORS PART. HUM	FACTORS DRY WET	FACTORS F
1	4200.	0.	118.	300.	4200.	118.	40.2	75.0	10.9	29.63	1.004	.997	.979	.998
2	4200.	0.	79.	300.	4200.	79.	29.8	75.0	9.7	29.63	.981	1.014	.983	.997
3	3400.	0.	111.	300.	3400.	111.	27.9	75.0	9.7	29.62	.981	1.014	.983	.997
4	2600.	0.	166.	300.	2600.	166.	28.5	74.0	9.6	29.62	.980	1.015	.983	.994
5	2600.	0.	110.	300.	2600.	110.	19.7	68.0	9.4	29.62	.976	1.018	.986	.977
6	2300.	0.	53.	300.	2300.	53.	9.9	75.0	9.4	29.61	.977	1.017	.990	.997
7	2000.	0.	224.	300.	2000.	224.	28.5	75.0	9.5	29.61	.978	1.017	.984	.997
8	2000.	0.	189.	300.	2000.	189.	24.3	74.0	9.4	29.60	.977	1.017	.985	.994
9	2000.	0.	112.	600.	2000.	112.	6.9	74.0	9.2	29.59	.973	1.021	.988	.994
10	2000.	0.	25.	600.	2000.	25.	5.0	75.0	9.4	29.59	.976	1.018	.992	.997
11	1500.	0.	33.	600.	1500.	33.	4.3	75.0	9.4	29.58	.976	1.018	.992	.998
12	900.	0.	3.	1200.	900.	3.	1.1	75.0	8.8	29.58	.967	1.026	.993	.997
13	765.	0.	4.	1200.	765.	4.	1.0	78.0	8.7	29.56	.965	1.027	.991	1.006

MODE	BHP FROM WORK	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2	WEIGHTED RESULTS MODE WF	POWER BHP	FUEL LB/HR	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2
1	95.0	.00	52.5	527.4	13.34	55831.	.077	7.3	3.09	.00	4.04	40.57	1.03	4295.
2	63.0	7.51	204.8	351.8	13.09	41145.	.077	4.8	2.29	.58	15.75	27.06	1.01	3165.
3	72.0	4.69	105.4	365.7	7.60	38606.	.077	5.5	2.15	.36	8.10	28.13	.58	2970.
4	82.0	1.91	37.9	356.9	4.22	39622.	.077	6.3	2.20	.15	2.91	27.45	.32	3048.
5	54.0	1.61	44.5	146.2	6.92	27283.	.077	4.2	1.51	.12	3.42	11.24	.53	2099.
6	24.0	2.98	47.5	43.6	9.55	13645.	.077	1.8	.76	.23	3.65	3.35	.73	1050.
7	86.0	1.30	209.4	332.2	9.46	39247.	.077	6.6	2.19	.10	16.11	25.55	.73	3019.
8	73.0	.61	58.9	300.3	3.82	33725.	.077	5.6	1.87	.05	4.53	23.10	.29	2594.
9	43.0	.57	9.0	70.1	1.40	9596.	.077	3.3	.53	.04	.69	5.39	.11	738.
10	9.0	3.66	51.6	12.8	1.62	6890.	.077	.7	.39	.28	3.97	.98	.12	530.
11	9.0	2.41	21.6	10.4	1.42	5911.	.077	.7	.33	.19	1.66	.80	.11	455.
12	.0	2.37	13.8	3.4	.27	1489.	.077	.0	.08	.18	1.06	.26	.02	115.
13	1.0	2.00	9.9	4.2	.31	1379.	.077	.1	.08	.15	.76	.32	.02	106.
							TOTAL	47.0	17.5	2.4	66.7	194.2	5.6	24182.

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA PNGV ENGINE EMISSION RESULTS PROJECT NO. 02-5137-434

ENGINE NUMBER
ENGINE MODEL 98 MB OM 611
ENGINE 2.2 L(134. CID) I4 CYL
ENGINE CYCLE DIESEL
ENGINE SERIAL DE 22 LA

TEST B20-2E RUN
DATE 3/23/98 TIME
COMPUTER PROGRAM SSDIL 1.3 -R
CELL 4 BAG CART 1

DIESEL B20 EM-2565-F
HCR 1.99
C:.837 H:.140 O:.023 X:.000
ENGINE OIL
DENS. 6.893

MODE	TARGET SPEED RPM	TARGET LOAD PCT	TARGET TORQUE LB-FT	MEASURED TIME SEC	MEASURED SPEED RPM	MEASURED TORQUE LB-FT	C - B FUEL LB/HR	INTAKE AIR TEMP DEG F	INTAKE AIR HUMID G/KG	INTAKE AIR BARO IN-HG	FACTORS NOx HUM	FACTORS PART. HUM	FACTORS DRY WET	FACTORS F
1	4200.	0.	116.	300.	4200.	116.	42.6	75.0	9.6	29.19	.980	1.015	.972	1.007
2	4200.	0.	78.	300.	4200.	78.	30.5	75.0	9.6	29.18	.980	1.015	.977	1.007
3	3400.	0.	112.	300.	3400.	112.	29.0	75.0	9.3	29.18	.975	1.019	.977	1.007
4	2600.	0.	167.	300.	2600.	167.	29.8	75.0	8.7	29.17	.965	1.028	.974	1.007
5	2600.	0.	112.	300.	2600.	112.	20.5	75.0	8.7	29.16	.965	1.028	.980	1.007
6	2300.	0.	52.	300.	2300.	52.	10.0	75.0	8.8	29.15	.967	1.026	.982	1.007
7	2000.	0.	220.	300.	2000.	220.	30.0	75.0	9.0	29.15	.969	1.024	.975	1.008
8	2000.	0.	190.	300.	2000.	190.	25.1	75.0	9.0	29.14	.969	1.024	.977	1.008
9	2000.	0.	110.	300.	2000.	110.	15.2	76.0	8.8	29.13	.966	1.026	.981	1.011
10	2000.	0.	25.	600.	2000.	25.	5.2	75.0	9.0	29.13	.970	1.023	.985	1.008
11	1500.	0.	33.	600.	1500.	33.	4.5	75.0	8.7	29.11	.965	1.027	.984	1.008
12	900.	0.	1.	1200.	900.	1.	1.0	80.0	9.0	29.10	.969	1.024	.985	1.023
13	765.	0.	1.	1200.	765.	1.	.9	83.0	8.8	29.10	.967	1.026	.986	1.031

MODE	BHP FROM WORK	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2	WEIGHTED RESULTS MODE WF	POWER BHP	FUEL LB/HR	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2
1	94.0	4.82	54.3	526.7	14.66	59137.	.077	7.2	3.28	.37	4.18	40.52	1.13	4549.
2	63.0	8.97	194.0	355.9	13.87	42045.	.077	4.8	2.34	.69	14.93	27.38	1.07	3234.
3	73.0	4.98	94.0	380.2	6.99	40109.	.077	5.6	2.23	.38	7.23	29.25	.54	3085.
4	83.0	2.28	38.2	363.4	4.57	41358.	.077	6.4	2.29	.18	2.94	27.96	.35	3181.
5	56.0	2.30	46.8	172.9	6.40	28466.	.077	4.3	1.58	.18	3.60	13.30	.49	2190.
6	23.0	3.36	48.1	43.9	6.04	13822.	.077	1.8	.77	.26	3.70	3.38	.46	1063.
7	85.0	1.98	237.9	324.3	10.23	41376.	.077	6.5	2.31	.15	18.30	24.95	.79	3183.
8	73.0	1.57	79.0	300.6	4.44	34778.	.077	5.6	1.93	.12	6.08	23.12	.34	2675.
9	42.0	.98	22.6	158.0	3.08	21046.	.077	3.2	1.17	.08	1.74	12.15	.24	1619.
10	9.0	3.86	50.8	11.7	1.65	7200.	.077	.7	.40	.30	3.91	.90	.13	554.
11	10.0	1.78	22.8	9.5	1.55	6236.	.077	.8	.35	.14	1.75	.73	.12	480.
12	.0	1.41	14.1	1.3	.31	1343.	.077	.0	.08	.11	1.09	.10	.02	103.
13	.0	1.96	13.0	1.5	.36	1204.	.077	.0	.07	.15	1.00	.11	.03	93.
							TOTAL	47.0	18.8	3.1	70.4	203.9	5.7	26009.

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA PNGV ENGINE EMISSION RESULTS PROJECT NO. 02-5137-434

ENGINE NUMBER
ENGINE MODEL 98 MB OM 611
ENGINE 2.2 L(134. CID) I4 CYL
ENGINE CYCLE DIESEL
ENGINE SERIAL DE 22 LA

TEST B20-3E RUN
DATE 3/25/98 TIME
COMPUTER PROGRAM SSDIL 1.3 -R
CELL 4 BAG CART 1

DIESEL B20 EM-2565-F
HCR 1.99
C:.837 H:.140 O:.023 X:.000
ENGINE OIL
DENS. 6.893

MODE	TARGET SPEED RPM	TARGET LOAD PCT	TARGET TORQUE LB-FT	MEASURED TIME SEC	MEASURED SPEED RPM	MEASURED TORQUE LB-FT	C - B FUEL LB/HR	INTAKE AIR TEMP DEG F	INTAKE AIR HUMID G/KG	INTAKE AIR BARO IN-HG	FACTORS NOx HUM	FACTORS PART. HUM	FACTORS DRY WET	FACTORS F
1	4200.	0.	117.	300.	4200.	117.	40.5	73.0	9.0	29.17	.970	1.023	.968	1.002
2	4200.	0.	78.	300.	4200.	78.	30.2	73.0	8.8	29.16	.966	1.026	.971	1.001
3	3400.	0.	111.	300.	3400.	111.	29.3	73.0	8.8	29.15	.967	1.026	.972	1.002
4	2600.	0.	167.	300.	2600.	167.	29.7	73.0	8.8	29.15	.967	1.026	.968	1.002
5	2600.	0.	112.	300.	2600.	112.	20.6	73.0	8.8	29.15	.967	1.026	.973	1.002
6	2300.	0.	53.	300.	2300.	53.	10.1	73.0	9.0	29.15	.970	1.023	.977	1.002
7	2000.	0.	222.	300.	2000.	222.	30.3	73.0	8.7	29.14	.965	1.027	.971	1.002
8	2000.	0.	189.	300.	2000.	189.	25.1	73.0	8.5	29.14	.961	1.031	.973	1.002
9	2000.	0.	112.	300.	2000.	112.	14.9	74.0	8.1	29.14	.955	1.035	.976	1.004
10	2000.	0.	25.	600.	2000.	25.	5.6	73.0	8.3	29.13	.958	1.033	.981	1.002
11	1500.	0.	34.	600.	1500.	34.	4.5	74.0	8.5	29.12	.961	1.031	.981	1.005
12	900.	0.	1.	1200.	900.	1.	1.1	78.0	9.2	29.12	.973	1.021	.980	1.017
13	765.	0.	2.	1200.	768.	2.	.9	80.0	9.3	29.11	.975	1.019	.983	1.023

MODE	BHP FROM WORK	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2	WEIGHTED RESULTS MODE WF	POWER BHP	FUEL LB/HR	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2
1	94.0	5.16	51.4	511.9	14.04	56278.	.077	7.2	3.12	.40	3.95	39.38	1.08	4329.
2	62.0	8.47	195.2	341.2	12.98	41647.	.077	4.8	2.32	.65	15.02	26.25	1.00	3204.
3	72.0	5.05	101.9	364.7	6.82	40524.	.077	5.5	2.25	.39	7.84	28.05	.52	3117.
4	84.0	2.42	36.3	359.1	4.43	41221.	.077	6.5	2.28	.19	2.79	27.63	.34	3171.
5	57.0	.73	43.0	173.0	5.93	28632.	.077	4.4	1.59	.06	3.31	13.31	.46	2202.
6	23.0	3.53	46.7	42.3	5.56	13913.	.077	1.8	.77	.27	3.59	3.25	.43	1070.
7	85.0	1.96	239.6	321.3	10.21	41824.	.077	6.5	2.33	.15	18.43	24.71	.79	3217.
8	72.0	1.58	65.4	300.5	3.91	34858.	.077	5.5	1.93	.12	5.03	23.11	.30	2681.
9	43.0	1.16	18.0	151.1	3.12	20711.	.077	3.3	1.15	.09	1.39	11.62	.24	1593.
10	10.0	3.56	50.4	14.0	1.57	7726.	.077	.8	.43	.27	3.88	1.07	.12	594.
11	10.0	2.30	21.9	10.2	1.53	6277.	.077	.8	.35	.18	1.68	.79	.12	483.
12	.0	2.13	14.3	3.1	.30	1460.	.077	.0	.08	.16	1.10	.24	.02	112.
13	.0	2.59	14.1	2.7	.30	1249.	.077	.0	.07	.20	1.09	.21	.02	96.
							TOTAL	47.1	18.7	3.1	69.1	199.6	5.4	25871.

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA PNGV ENGINE EMISSION RESULTS PROJECT NO. 02-5137-434

ENGINE NUMBER	TEST FT20-1E RUN	DIESEL FT20	EM-2564-F
ENGINE MODEL 98 MB OM 611	DATE 3/ 9/98 TIME	HCR 2.05	
ENGINE .0 L(2. CID) I4 CYL	COMPUTER PROGRAM SSDIL 1.3 -R	C:.853 H:.147 O:.000 X:.000	
ENGINE CYCLE DIESEL	CELL 4 BAG CART 1	ENGINE OIL	
ENGINE SERIAL DE 22 LA		DENS. 6.726	

MODE	TARGET SPEED RPM	TARGET LOAD PCT	TARGET TORQUE LB-FT	MEASURED TIME SEC	MEASURED SPEED RPM	MEASURED TORQUE LB-FT	C - B FUEL LB/HR	INTAKE AIR TEMP DEG F	INTAKE AIR HUMID G/KG	INTAKE AIR BARO IN-HG	FACTORS NOx HUM	FACTORS PART. HUM	FACTORS DRY WET	FACTORS F
1	4200.	0.	116.	300.	4200.	116.	37.2	75.0	9.9	29.42	.985	1.011	.980	1.002
2	4200.	0.	79.	300.	4200.	79.	27.7	75.0	10.0	29.42	.987	1.010	.985	1.002
3	3400.	0.	111.	300.	3400.	111.	26.0	75.0	10.0	29.42	.988	1.009	.985	1.002
4	2600.	0.	167.	300.	2600.	167.	27.0	74.0	10.0	29.42	.988	1.009	.985	.999
5	2600.	0.	112.	300.	2600.	112.	19.0	74.0	10.0	29.42	.987	1.010	.986	.999
6	2300.	0.	53.	300.	2300.	53.	9.0	75.0	10.0	29.41	.988	1.009	.993	1.002
7	2000.	0.	227.	300.	2000.	227.	29.8	75.0	9.5	29.41	.979	1.016	.984	1.002
8	2000.	0.	190.	300.	2000.	190.	24.2	74.0	8.9	29.40	.969	1.024	.987	.999
9	2000.	0.	111.	300.	2000.	111.	14.0	73.0	9.2	29.40	.974	1.020	.991	.996
10	2000.	0.	25.	600.	2000.	25.	4.9	74.0	9.4	29.39	.977	1.017	.994	.999
11	1500.	0.	34.	600.	1500.	34.	4.1	73.0	9.5	29.38	.979	1.016	.994	.997
12	900.	0.	2.	1200.	900.	2.	1.0	74.0	9.4	29.37	.977	1.017	.996	1.000
13	765.	0.	3.	1200.	766.	3.	.9	73.0	9.9	29.36	.986	1.011	.996	.998

MODE	BHP FROM WORK	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2	WEIGHTED RESULTS MODE WF	POWER BHP	FUEL LB/HR	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2
1	94.0	3.92	49.2	483.2	15.50	52627.	.077	7.2	2.86	.30	3.79	37.17	1.19	4048.
2	64.0	6.99	184.0	325.0	14.10	38978.	.077	4.9	2.13	.54	14.15	25.00	1.08	2998.
3	72.0	3.72	97.2	347.1	7.48	36710.	.077	5.5	2.00	.29	7.48	26.70	.58	2824.
4	83.0	1.35	37.3	334.5	4.65	38162.	.077	6.4	2.07	.10	2.87	25.73	.36	2936.
5	56.0	1.74	41.1	135.6	7.54	26835.	.077	4.3	1.46	.13	3.16	10.43	.58	2064.
6	24.0	3.07	44.0	39.9	6.40	12713.	.077	1.8	.69	.24	3.38	3.07	.49	978.
7	87.0	1.43	247.1	315.9	11.27	41789.	.077	6.7	2.29	.11	19.01	24.30	.87	3215.
8	73.0	1.09	75.2	281.3	5.02	34194.	.077	5.6	1.86	.08	5.78	21.64	.39	2630.
9	42.0	.67	17.6	133.5	3.31	19765.	.077	3.2	1.07	.05	1.35	10.27	.25	1520.
10	10.0	3.43	45.4	10.7	1.67	6858.	.077	.8	.38	.26	3.49	.82	.13	528.
11	10.0	1.29	21.8	7.8	1.66	5818.	.077	.8	.32	.10	1.67	.60	.13	448.
12	.0	.00	9.2	3.3	.26	1354.	.077	.0	.07	.00	.71	.26	.02	104.
13	1.0	.70	8.3	3.7	.27	1327.	.077	.1	.07	.05	.64	.29	.02	102.
							TOTAL	47.4	17.3	2.3	67.5	186.3	6.1	24395.

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA PNGV ENGINE EMISSION RESULTS PROJECT NO. 02-5137-434

ENGINE NUMBER
ENGINE MODEL 98 MB OM 611
ENGINE .0 L(2. CID) I4 CYL
ENGINE CYCLE DIESEL
ENGINE SERIAL DE 22 LA

TEST FT20-2E RUN
DATE 3/17/98 TIME
COMPUTER PROGRAM SSDIL 1.3 -R
CELL 4 BAG CART 1

DIESEL FT20 EM-2564-F
HCR 2.05
C:.853 H:.147 O:.000 X:.000
ENGINE OIL
DENS. 6.726

MODE	TARGET SPEED RPM	TARGET LOAD PCT	TARGET TORQUE LB-FT	MEASURED TIME SEC	MEASURED SPEED RPM	MEASURED TORQUE LB-FT	C - B FUEL LB/HR	INTAKE AIR TEMP DEG F	INTAKE AIR HUMID G/KG	INTAKE AIR BARO IN-HG	FACTORS NOx HUM	FACTORS PART. HUM	FACTORS DRY WET	FACTORS F
1	4200.	0.	117.	300.	4200.	117.	39.4	73.0	9.7	28.95	.982	1.014	.973	1.007
2	4200.	0.	79.	300.	4200.	79.	29.5	73.0	9.4	28.95	.976	1.018	.977	1.007
3	3400.	0.	11.	300.	3400.	11.	27.6	73.0	8.9	28.95	.967	1.025	.977	1.007
4	2600.	0.	167.	300.	2600.	167.	29.4	73.0	9.1	28.94	.971	1.022	.978	1.007
5	2600.	0.	111.	300.	2600.	111.	19.9	73.0	9.0	28.94	.970	1.023	.982	1.007
6	2300.	0.	53.	300.	2300.	53.	9.6	73.0	9.2	28.93	.974	1.020	.982	1.007
7	2000.	0.	225.	300.	2000.	225.	29.3	73.0	9.6	28.93	.980	1.015	.975	1.008
8	2000.	0.	190.	300.	2000.	190.	24.3	73.0	9.4	28.92	.976	1.018	.976	1.008
9	2000.	0.	112.	300.	2000.	112.	14.7	73.0	9.4	28.92	.976	1.018	.983	1.008
10	2000.	0.	26.	600.	2000.	26.	5.5	72.0	8.9	28.92	.968	1.025	.987	1.005
11	1500.	0.	33.	600.	1500.	33.	4.2	71.0	8.4	28.91	.960	1.031	.986	1.001
12	900.	0.	2.	1200.	900.	2.	1.0	74.0	9.1	28.91	.972	1.022	.988	1.011
13	765.	0.	3.	1200.	764.	3.	.9	77.0	9.4	28.89	.976	1.018	.988	1.020

MODE	BHP FROM WORK	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2	WEIGHTED RESULTS MODE WF	POWER BHP	FUEL LB/HR	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2
1	94.0	4.12	51.3	501.9	14.86	55709.	.077	7.2	3.03	.32	3.94	38.60	1.14	4285.
2	63.0	5.82	174.4	335.0	14.14	41572.	.077	4.8	2.27	.45	13.41	25.77	1.09	3198.
3	71.0	3.81	95.0	342.4	6.36	38961.	.077	5.5	2.12	.29	7.31	26.34	.49	2997.
4	83.0	2.00	37.4	342.9	4.82	41603.	.077	6.4	2.26	.15	2.87	26.38	.37	3200.
5	55.0	1.88	44.1	147.6	7.42	28072.	.077	4.2	1.53	.14	3.39	11.35	.57	2159.
6	23.0	2.83	46.1	40.6	6.23	13456.	.077	1.8	.73	.22	3.54	3.12	.48	1035.
7	87.0	1.43	269.4	318.7	11.98	41134.	.077	6.7	2.26	.11	20.72	24.52	.92	3164.
8	73.0	1.12	91.5	285.1	5.36	34264.	.077	5.6	1.87	.09	7.04	21.93	.41	2636.
9	43.0	.89	21.4	142.4	3.25	20849.	.077	3.3	1.13	.07	1.64	10.96	.25	1604.
10	10.0	3.26	47.8	10.9	1.74	7684.	.077	.8	.42	.25	3.68	.84	.13	591.
11	10.0	2.21	22.0	7.3	1.56	5933.	.077	.8	.32	.17	1.69	.56	.12	456.
12	.0	.21	10.1	2.8	.23	1372.	.077	.0	.08	.02	.78	.21	.02	106.
13	1.0	.00	9.2	3.1	.25	1205.	.077	.1	.07	.00	.71	.24	.02	93.
							TOTAL	47.2	18.1	2.3	70.7	190.8	6.0	25524.

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA PNGV ENGINE EMISSION RESULTS PROJECT NO. 02-5137-434

ENGINE NUMBER
ENGINE MODEL 98 MB OM 611
ENGINE 2.2 L(134. CID) I4 CYL
ENGINE CYCLE DIESEL
ENGINE SERIAL DE 22 LA

TEST FT20-3E RUN
DATE 3/30/98 TIME
COMPUTER PROGRAM SSDIL 1.3 -R
CELL 4 BAG CART 1

DIESEL FT20 EM-2564-F
HCR 2.05
C:.853 H:.147 O:.000 X:.000
ENGINE OIL
DENS. 6.726

MODE	TARGET SPEED RPM	TARGET LOAD PCT	TARGET TORQUE LB-FT	MEASURED TIME SEC	MEASURED SPEED RPM	MEASURED TORQUE LB-FT	C - B FUEL LB/HR	INTAKE AIR TEMP DEG F	INTAKE AIR HUMID G/KG	INTAKE AIR BARO IN-HG	FACTORS NOx HUM	FACTORS PART. HUM	FACTORS DRY WET	FACTORS F
1	4200.	0.	117.	300.	4200.	117.	39.4	72.0	9.4	28.72	.977	1.017	.964	1.010
2	4200.	0.	78.	300.	4200.	78.	28.9	73.0	9.4	28.72	.977	1.017	.968	1.013
3	3400.	0.	111.	300.	3400.	111.	26.7	73.0	9.4	28.71	.977	1.017	.969	1.013
4	2600.	0.	167.	300.	2600.	167.	28.4	73.0	9.1	28.70	.972	1.022	.968	1.013
5	2600.	0.	111.	300.	2600.	111.	19.4	72.0	8.8	28.69	.967	1.026	.971	1.010
6	2300.	0.	52.	300.	2300.	52.	9.4	73.0	8.6	28.69	.963	1.029	.974	1.013
7	2000.	0.	227.	300.	2000.	227.	29.4	73.0	8.6	28.68	.964	1.028	.965	1.013
8	2000.	0.	190.	300.	2000.	190.	25.1	73.0	8.5	28.67	.961	1.030	.966	1.013
9	2000.	0.	111.	300.	2000.	111.	14.0	73.0	8.3	28.67	.957	1.034	.970	1.013
10	2000.	0.	24.	600.	2000.	24.	4.9	72.0	8.2	28.66	.956	1.035	.974	1.010
11	1500.	0.	34.	600.	1500.	34.	4.4	74.0	8.3	28.65	.958	1.033	.975	1.016
12	900.	0.	2.	1200.	900.	2.	1.0	80.0	9.4	28.64	.976	1.018	.978	1.035
13	765.	0.	3.	1200.	765.	3.	.8	82.0	9.3	28.63	.976	1.019	.978	1.041

MODE	BHP FROM WORK	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2	WEIGHTED RESULTS MODE WF	POWER BHP	FUEL LB/HR	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2
1	94.0	4.85	52.3	502.1	15.66	55754.	.077	7.2	3.03	.37	4.03	38.62	1.20	4289.
2	63.0	7.92	191.5	330.3	13.95	40563.	.077	4.8	2.22	.61	14.73	25.41	1.07	3120.
3	72.0	4.58	94.1	352.5	7.44	37731.	.077	5.5	2.06	.35	7.24	27.11	.57	2902.
4	84.0	2.24	36.9	346.8	4.94	40186.	.077	6.5	2.18	.17	2.83	26.68	.38	3091.
5	56.0	2.24	41.1	143.2	7.43	27490.	.077	4.3	1.50	.17	3.16	11.02	.57	2115.
6	23.0	3.19	44.8	40.0	6.02	13287.	.077	1.8	.73	.25	3.45	3.08	.46	1022.
7	87.0	1.93	246.2	319.6	12.01	41297.	.077	6.7	2.26	.15	18.94	24.58	.92	3177.
8	73.0	1.64	70.7	290.8	4.81	35404.	.077	5.6	1.93	.13	5.44	22.37	.37	2723.
9	43.0	1.16	17.7	137.8	3.07	19746.	.077	3.3	1.07	.09	1.36	10.60	.24	1519.
10	9.0	4.01	47.1	10.1	1.39	6920.	.077	.7	.38	.31	3.62	.77	.11	532.
11	10.0	2.19	21.9	7.1	1.54	6204.	.077	.8	.34	.17	1.68	.54	.12	477.
12	1.0	1.40	11.5	1.7	.23	1340.	.077	.1	.07	.11	.88	.13	.02	103.
13	1.0	.00	10.6	.4	.21	1153.	.077	.1	.06	.00	.81	.03	.02	89.
							TOTAL	47.4	17.8	2.9	68.2	190.9	6.1	25159.

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA PNGV ENGINE EMISSION RESULTS PROJECT NO. 02-5137-434

ENGINE NUMBER
ENGINE MODEL 98 MB OM 611
ENGINE .0 L(2. CID) I4 CYL
ENGINE CYCLE DIESEL
ENGINE SERIAL DE 22 LA

TEST FT100-1E RUN
DATE 3/10/98 TIME
COMPUTER PROGRAM SSDIL 1.3 -R
CELL 4 BAG CART 1

DIESEL FT100 EM-2563-F
HCR 2.14
C:.848 H:.152 O:.000 X:.000
ENGINE OIL
DENS. 6.518

MODE	TARGET SPEED RPM	TARGET LOAD PCT	TARGET TORQUE LB-FT	MEASURED TIME SEC	MEASURED SPEED RPM	MEASURED TORQUE LB-FT	C - B FUEL LB/HR	INTAKE AIR TEMP DEG F	INTAKE AIR HUMID G/KG	INTAKE AIR BARO IN-HG	FACTORS NOx HUM	FACTORS PART. HUM	FACTORS DRY WET	FACTORS F
1	4200.	0.	118.	300.	4200.	118.	37.7	75.0	9.7	29.65	.981	1.014	.981	.996
2	4200.	0.	78.	300.	4200.	78.	27.2	74.0	9.7	29.65	.981	1.014	.985	.993
3	3400.	0.	111.	300.	3400.	111.	26.1	75.0	9.7	29.65	.981	1.014	.986	.996
4	2600.	0.	167.	300.	2600.	167.	26.3	75.0	9.7	29.65	.981	1.014	.985	.996
5	2600.	0.	111.	300.	2600.	111.	18.9	75.0	9.7	29.65	.981	1.014	.989	.996
6	2300.	0.	53.	300.	2300.	53.	9.0	75.0	9.8	29.64	.984	1.012	.993	.997
7	2000.	0.	226.	300.	2000.	226.	28.0	76.0	9.8	29.64	.984	1.012	.984	1.000
8	2000.	0.	190.	300.	2000.	190.	23.9	74.0	9.7	29.63	.981	1.014	.986	.994
9	2000.	0.	111.	300.	2000.	111.	14.0	74.0	9.7	29.63	.981	1.014	.990	.994
10	2000.	0.	26.	600.	2000.	26.	5.0	75.0	9.8	29.62	.984	1.012	.994	.997
11	1500.	0.	34.	600.	1500.	34.	4.1	76.0	9.4	29.61	.976	1.018	.994	1.000
12	900.	0.	1.	1200.	900.	1.	.9	75.0	9.2	29.60	.973	1.021	.996	.997
13	765.	0.	4.	1200.	765.	4.	.9	75.0	9.8	29.58	.984	1.012	.996	.998

MODE	BHP FROM WORK	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2	WEIGHTED RESULTS MODE WF	POWER BHP	FUEL LB/HR	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2
1	94.0	3.54	48.8	488.0	13.13	53013.	.077	7.2	2.90	.27	3.75	37.54	1.01	4078.
2	63.0	6.24	181.5	313.5	12.37	38005.	.077	4.8	2.09	.48	13.96	24.12	.95	2923.
3	72.0	3.69	86.7	344.9	6.75	36600.	.077	5.5	2.01	.28	6.67	26.53	.52	2815.
4	83.0	1.79	34.7	338.8	4.13	36934.	.077	6.4	2.02	.14	2.67	26.06	.32	2841.
5	55.0	1.28	37.2	143.9	6.24	26560.	.077	4.2	1.45	.10	2.86	11.07	.48	2043.
6	23.0	2.34	38.3	42.7	4.85	12632.	.077	1.8	.69	.18	2.95	3.29	.37	972.
7	86.0	1.47	212.8	323.1	8.45	39103.	.077	6.6	2.15	.11	16.37	24.85	.65	3008.
8	73.0	1.05	72.6	283.5	4.28	33589.	.077	5.6	1.84	.08	5.59	21.81	.33	2584.
9	43.0	.47	17.3	140.3	2.69	19658.	.077	3.3	1.07	.04	1.33	10.79	.21	1512.
10	10.0	2.65	35.4	11.9	1.51	7041.	.077	.8	.39	.20	2.72	.92	.12	542.
11	10.0	1.30	18.5	8.1	1.30	5802.	.077	.8	.32	.10	1.42	.62	.10	446.
12	.0	.41	8.3	2.8	.24	1299.	.077	.0	.07	.03	.64	.22	.02	100.
13	.0	.43	5.4	3.2	.27	1193.	.077	.0	.07	.03	.41	.25	.02	92.
							TOTAL	47.1	17.1	2.0	61.3	188.1	5.1	23956.

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA PNGV ENGINE EMISSION RESULTS PROJECT NO. 02-5137-434

ENGINE NUMBER
ENGINE MODEL 98 MB OM 611
ENGINE .0 L(2. CID) I4 CYL
ENGINE CYCLE DIESEL
ENGINE SERIAL DE 22 LA

TEST FT100-2E RUN
DATE 3/13/98 TIME
COMPUTER PROGRAM SSDIL 1.3 -R
CELL 4 BAG CART 1

DIESEL FT100 EM-2563-F
HCR 2.14
C:.848 H:.152 O:.000 X:.000
ENGINE OIL
DENS. 6.518

MODE	TARGET SPEED RPM	TARGET LOAD PCT	TARGET TORQUE LB-FT	MEASURED TIME SEC	MEASURED SPEED RPM	MEASURED TORQUE LB-FT	C - B FUEL LB/HR	INTAKE AIR TEMP DEG F	INTAKE AIR HUMID G/KG	INTAKE AIR BARO IN-HG	FACTORS NOx HUM	FACTORS PART. HUM	FACTORS DRY WET	FACTORS F
1	4200.	0.	118.	300.	4200.	118.	39.1	75.0	10.0	29.44	.988	1.009	.973	1.002
2	4200.	0.	79.	300.	4200.	79.	27.8	75.0	10.2	29.44	.992	1.006	.978	1.002
3	3400.	0.	112.	300.	3400.	112.	27.0	75.0	9.9	29.44	.985	1.011	.978	1.001
4	2600.	0.	167.	300.	2600.	167.	27.8	75.0	9.1	29.44	.972	1.022	.976	1.001
5	2600.	0.	111.	300.	2600.	111.	19.1	75.0	9.5	29.44	.978	1.017	.981	1.001
6	2300.	0.	53.	300.	2300.	53.	8.9	75.0	9.2	29.43	.973	1.020	.984	1.001
7	2000.	0.	224.	300.	2000.	224.	28.7	75.0	9.4	29.43	.977	1.017	.976	1.001
8	2000.	0.	190.	300.	2000.	190.	23.4	74.0	9.4	29.43	.977	1.017	.977	.998
9	2000.	0.	112.	300.	2000.	112.	14.5	75.0	9.2	29.42	.973	1.020	.982	1.001
10	2000.	0.	25.	600.	2000.	25.	4.9	76.0	9.4	29.42	.977	1.017	.986	1.004
11	1500.	0.	33.	600.	1500.	33.	4.3	74.0	9.5	29.40	.979	1.016	.985	.999
12	900.	0.	2.	1200.	900.	2.	1.0	78.0	9.5	29.40	.979	1.016	.986	1.011
13	765.	0.	2.	1200.	765.	2.	.9	77.0	9.5	29.40	.978	1.016	.986	1.008

MODE	BHP FROM WORK	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2	WEIGHTED RESULTS MODE WF	POWER BHP	FUEL LB/HR	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2
1	94.8	3.10	52.9	497.0	14.04	54983.	.077	7.3	3.01	.24	4.07	38.23	1.08	4229.
2	63.0	6.83	184.7	330.7	12.37	38870.	.077	4.8	2.14	.53	14.21	25.44	.95	2990.
3	73.0	3.68	86.1	355.5	7.06	37911.	.077	5.6	2.08	.28	6.62	27.34	.54	2916.
4	83.0	1.13	36.0	342.3	4.27	39092.	.077	6.4	2.14	.09	2.77	26.33	.33	3007.
5	56.0	.83	36.3	151.6	6.01	26895.	.077	4.3	1.47	.06	2.79	11.66	.46	2069.
6	23.0	2.31	36.4	41.6	5.00	12520.	.077	1.8	.69	.18	2.80	3.20	.38	963.
7	86.0	1.00	234.6	315.9	9.17	40050.	.077	6.6	2.21	.08	18.04	24.30	.71	3081.
8	73.0	.43	61.0	288.7	3.89	32935.	.077	5.6	1.80	.03	4.69	22.20	.30	2533.
9	43.0	.00	16.8	140.0	2.83	20337.	.077	3.3	1.11	.00	1.29	10.77	.22	1564.
10	9.0	2.16	35.7	10.9	1.42	6872.	.077	.7	.38	.17	2.75	.84	.11	529.
11	10.0	.72	18.0	8.5	1.29	6025.	.077	.8	.33	.06	1.39	.65	.10	463.
12	1.5	.24	9.1	2.1	.23	1400.	.077	.1	.08	.02	.70	.17	.02	108.
13	2.0	.58	8.0	2.2	.26	1250.	.077	.2	.07	.04	.61	.17	.02	96.
							TOTAL	47.5	17.5	1.8	62.7	191.3	5.2	24549.

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA PNGV ENGINE EMISSION RESULTS PROJECT NO. 02-5137-434

ENGINE NUMBER	TEST FT100-3E RUN	DIESEL FT100 EM-2563-F
ENGINE MODEL 98 MB OM 611	DATE 4/ 2/98 TIME	HCR 2.14
ENGINE 2.2 L(134. CID) I4 CYL	COMPUTER PROGRAM SSDIL 1.3 -R	C:.848 H:.152 O:.000 X:.000
ENGINE CYCLE DIESEL	CELL 4 BAG CART 1	ENGINE OIL
ENGINE SERIAL DE 22 LA		DENS. 6.518

MODE	TARGET SPEED RPM	TARGET LOAD PCT	TARGET TORQUE LB-FT	MEASURED TIME SEC	MEASURED SPEED RPM	MEASURED TORQUE LB-FT	C - B FUEL LB/HR	INTAKE AIR TEMP DEG F	INTAKE AIR HUMID G/KG	INTAKE AIR BARO IN-HG	FACTORS NOx HUM	FACTORS PART. HUM	FACTORS DRY WET	FACTORS F
1	4200.	0.	12.	300.	4200.	12.	39.9	73.0	9.4	28.96	.976	1.018	.967	1.007
2	4200.	0.	78.	300.	4200.	78.	28.6	73.0	9.4	28.96	.976	1.018	.971	1.007
3	3400.	0.	112.	300.	3400.	112.	28.1	73.0	9.2	28.95	.974	1.020	.971	1.007
4	2600.	0.	167.	300.	2600.	167.	28.5	73.0	8.9	28.95	.968	1.025	.973	1.007
5	2600.	0.	110.	300.	2600.	110.	19.5	73.0	8.7	28.94	.964	1.028	.976	1.007
6	2300.	0.	54.	300.	2300.	54.	9.9	73.0	8.5	28.93	.962	1.030	.980	1.007
7	2000.	0.	224.	300.	2000.	224.	29.1	74.0	8.6	28.93	.963	1.029	.972	1.009
8	2000.	0.	190.	300.	2000.	190.	24.6	74.0	8.7	28.93	.964	1.028	.974	1.010
9	2000.	0.	111.	300.	2000.	111.	14.6	74.0	8.6	28.92	.963	1.029	.977	1.010
10	2000.	0.	24.	600.	2000.	24.	5.0	72.0	8.8	28.92	.966	1.026	.979	1.004
11	1500.	0.	33.	600.	1500.	33.	4.3	73.0	8.4	28.91	.960	1.031	.979	1.007
12	900.	0.	3.	1200.	900.	3.	1.1	77.0	8.9	28.90	.968	1.025	.981	1.019
13	765.	0.	4.	1200.	765.	4.	.9	78.0	8.8	28.90	.966	1.026	.983	1.022

MODE	BHP FROM WORK	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2	WEIGHTED RESULTS MODE WF	POWER BHP	FUEL LB/HR	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2
1	93.0	4.98	56.5	489.6	14.45	56118.	.077	7.2	3.07	.38	4.35	37.66	1.11	4317.
2	63.0	8.22	179.1	328.7	12.52	39984.	.077	4.8	2.20	.63	13.77	25.28	.96	3076.
3	74.0	4.40	81.6	352.8	6.13	39454.	.077	5.7	2.16	.34	6.28	27.14	.47	3035.
4	84.0	2.23	37.3	339.1	4.19	40029.	.077	6.5	2.19	.17	2.87	26.08	.32	3079.
5	55.0	1.83	36.4	143.3	6.08	27475.	.077	4.2	1.50	.14	2.80	11.02	.47	2113.
6	24.0	2.49	36.8	42.2	5.26	13869.	.077	1.8	.76	.19	2.83	3.25	.40	1067.
7	86.0	1.77	230.0	312.2	9.86	40591.	.077	6.6	2.24	.14	17.69	24.02	.76	3122.
8	73.0	1.48	75.7	281.4	4.46	34574.	.077	5.6	1.89	.11	5.82	21.65	.34	2660.
9	43.0	.76	16.9	142.8	2.65	20540.	.077	3.3	1.12	.06	1.30	10.98	.20	1580.
10	9.0	2.52	35.8	11.0	1.32	7048.	.077	.7	.39	.19	2.75	.85	.10	542.
11	10.0	1.26	17.8	8.0	1.20	6029.	.077	.8	.33	.10	1.37	.62	.09	464.
12	1.0	.60	8.7	1.6	.21	1511.	.077	.1	.08	.05	.67	.12	.02	116.
13	1.0	.21	8.7	1.5	.22	1238.	.077	.1	.07	.02	.67	.11	.02	95.
							TOTAL	47.4	18.0	2.5	63.2	188.8	5.3	25266.

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH
EPA PNGV ENGINE EMISSION RESULTS PROJECT NO. 02-5137-434

ENGINE NUMBER
ENGINE MODEL 98 MB OM 611
ENGINE 2.2 L(134. CID) I4 CYL
ENGINE CYCLE DIESEL
ENGINE SERIAL DE 22 LA

TEST DMM 15-1E RUN
DATE 4/ 6/98 TIME
COMPUTER PROGRAM SSDIL 1.3 -R
CELL 4 BAG CART 1

DIESEL DMM15 EM-2568-F
HCR 2.06
C:.808 H:.140 O:.052 X:.000
ENGINE OIL
DENS. 6.818

MODE	TARGET SPEED RPM	TARGET LOAD PCT	TARGET TORQUE LB-FT	MEASURED TIME SEC	MEASURED SPEED RPM	MEASURED TORQUE LB-FT	C - B FUEL LB/HR	INTAKE AIR TEMP DEG F	INTAKE AIR HUMID G/KG	INTAKE AIR BARO IN-HG	FACTORS NOx HUM	FACTORS PART. HUM	FACTORS DRY WET	FACTORS F
1	4200.	0.	118.	300.	4200.	118.	43.8	74.0	9.6	28.82	.981	1.015	.964	1.013
2	4200.	0.	79.	300.	4200.	79.	31.4	73.0	9.4	28.82	.977	1.018	.969	1.010
3	3400.	0.	112.	300.	3400.	112.	29.0	73.0	9.3	28.82	.974	1.020	.972	1.010
4	2600.	0.	165.	300.	2600.	165.	29.4	73.0	9.1	28.81	.971	1.022	.972	1.010
5	2600.	0.	111.	300.	2600.	111.	20.6	72.0	8.8	28.81	.966	1.026	.974	1.007
6	2300.	0.	53.	300.	2300.	53.	9.9	72.0	8.7	28.80	.965	1.027	.979	1.007
7	2000.	0.	222.	300.	2000.	222.	30.5	73.0	8.6	28.80	.963	1.029	.971	1.010
8	2000.	0.	189.	300.	2000.	189.	25.3	72.0	8.5	28.79	.961	1.031	.971	1.007
9	2000.	0.	112.	300.	2000.	112.	15.4	71.0	8.7	28.79	.965	1.027	.973	1.005
10	2000.	0.	24.	600.	2000.	24.	5.3	71.0	8.8	28.80	.967	1.026	.977	1.005
11	1500.	0.	33.	600.	1500.	33.	4.4	70.0	8.9	28.80	.969	1.024	.980	1.002
12	900.	0.	3.	1200.	900.	3.	1.1	73.0	9.1	28.80	.972	1.021	.981	1.011
13	765.	0.	2.	1200.	766.	2.	.9	74.0	9.3	28.80	.975	1.019	.982	1.014

MODE	BHP FROM WORK	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2	WEIGHTED RESULTS MODE WF	POWER BHP	FUEL LB/HR	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2
1	96.0	5.12	65.0	492.1	11.18	58741.	.077	7.4	3.37	.39	5.00	37.86	.86	4519.
2	64.0	7.22	88.5	330.5	9.76	41988.	.077	4.9	2.41	.56	6.80	25.43	.75	3230.
3	73.0	4.19	49.9	350.1	5.30	38811.	.077	5.6	2.23	.32	3.84	26.93	.41	2985.
4	82.0	2.80	32.3	356.6	2.86	39402.	.077	6.3	2.26	.22	2.48	27.43	.22	3031.
5	56.0	3.04	39.5	153.8	4.82	27569.	.077	4.3	1.58	.23	3.04	11.83	.37	2121.
6	23.0	4.26	47.7	38.0	4.12	13212.	.077	1.8	.76	.33	3.67	2.92	.32	1016.
7	86.0	1.85	182.0	331.7	6.95	40643.	.077	6.6	2.35	.14	14.00	25.52	.53	3126.
8	73.0	1.23	55.2	302.3	2.71	33871.	.077	5.6	1.95	.09	4.25	23.25	.21	2605.
9	43.0	1.44	18.9	141.9	2.25	20685.	.077	3.3	1.19	.11	1.45	10.91	.17	1591.
10	9.0	6.01	63.0	11.5	.95	6951.	.077	.7	.40	.46	4.84	.88	.07	535.
11	10.0	2.07	23.3	8.6	.80	5921.	.077	.8	.34	.16	1.79	.66	.06	455.
12	.5	1.07	9.6	2.6	.19	1436.	.077	.0	.08	.08	.74	.20	.01	110.
13	.0	.46	8.3	3.3	.15	1242.	.077	.0	.07	.04	.64	.25	.01	96.
							TOTAL	47.3	19.0	3.1	52.6	194.1	4.0	25421.

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA PNGV ENGINE EMISSION RESULTS PROJECT NO. 02-5137-434

ENGINE NUMBER
ENGINE MODEL 98 MB OM 611
ENGINE 2.2 L(134. CID) I4 CYL
ENGINE CYCLE DIESEL
ENGINE SERIAL DE 22 LA

TEST DMM 15-2E RUN
DATE 4/ 7/98 TIME
COMPUTER PROGRAM SSDIL 1.3 -R
CELL 4 BAG CART 1

DIESEL DMM15 EM-2568-F
HCR 2.06
C:.808 H:.140 O:.052 X:.000
ENGINE OIL
DENS. 6.818

MODE	TARGET SPEED RPM	TARGET LOAD PCT	TARGET TORQUE LB-FT	MEASURED TIME SEC	MEASURED SPEED RPM	MEASURED TORQUE LB-FT	C - B FUEL LB/HR	INTAKE AIR TEMP DEG F	INTAKE AIR HUMID G/KG	INTAKE AIR BARO IN-HG	FACTORS NOx HUM	FACTORS PART. HUM	FACTORS DRY WET	FACTORS F
1	4200.	0.	118.	300.	4200.	118.	44.5	74.0	8.6	28.95	.962	1.029	.964	1.009
2	4200.	0.	79.	300.	4200.	79.	31.8	74.0	8.6	28.95	.962	1.029	.969	1.009
3	3400.	0.	112.	300.	3400.	112.	30.4	74.0	8.7	28.94	.964	1.028	.970	1.009
4	2600.	0.	166.	300.	2600.	166.	30.6	74.0	8.4	28.95	.960	1.032	.970	1.009
5	2600.	0.	111.	300.	2600.	111.	20.4	74.0	8.2	28.95	.956	1.035	.974	1.009
6	2300.	0.	53.	300.	2300.	53.	10.3	74.0	8.1	28.95	.955	1.036	.980	1.008
7	2000.	0.	224.	300.	2000.	224.	30.9	74.0	8.2	28.95	.957	1.034	.972	1.009
8	2000.	0.	189.	300.	2000.	189.	25.0	73.0	8.2	28.94	.956	1.035	.973	1.006
9	2000.	0.	112.	300.	2000.	112.	15.9	74.0	8.4	28.94	.960	1.032	.976	1.009
10	2000.	0.	25.	600.	2000.	25.	5.4	73.0	8.3	28.93	.959	1.032	.980	1.006
11	1500.	0.	33.	600.	1500.	33.	4.3	75.0	8.6	28.92	.963	1.029	.980	1.013
12	900.	0.	2.	1200.	900.	2.	1.1	81.0	9.3	28.92	.975	1.019	.981	1.031
13	765.	0.	2.	1200.	768.	2.	.9	84.0	8.9	28.91	.968	1.025	.981	1.039

MODE	BHP FROM WORK	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2	WEIGHTED MODE WF	WEIGHTED POWER BHP	WEIGHTED FUEL LB/HR	WEIGHTED GRAMS/HOUR HC	WEIGHTED GRAMS/HOUR CO	WEIGHTED GRAMS/HOUR NOx	WEIGHTED GRAMS/HOUR PART	WEIGHTED GRAMS/HOUR CO2
1	95.0	5.80	58.0	489.0	10.94	59673.	.077	7.3	3.43	.45	4.46	37.61	.84	4590.
2	64.0	6.65	79.2	286.5	8.99	42551.	.077	4.9	2.45	.51	6.09	22.04	.69	3273.
3	74.0	4.65	44.8	350.6	5.13	40795.	.077	5.7	2.34	.36	3.45	26.97	.39	3138.
4	82.0	3.13	30.7	359.8	2.63	41066.	.077	6.3	2.36	.24	2.36	27.68	.20	3159.
5	56.0	2.24	37.5	156.2	4.55	27271.	.077	4.3	1.57	.17	2.89	12.02	.35	2098.
6	24.0	3.02	50.1	40.2	4.07	13787.	.077	1.8	.79	.23	3.85	3.09	.31	1061.
7	86.0	2.25	218.0	327.8	7.94	41148.	.077	6.6	2.38	.17	16.77	25.21	.61	3165.
8	73.0	1.98	96.0	289.5	3.74	33367.	.077	5.6	1.92	.15	7.38	22.27	.29	2567.
9	43.0	1.66	18.9	154.4	2.08	21350.	.077	3.3	1.23	.13	1.46	11.88	.16	1642.
10	10.0	6.49	64.8	9.9	.93	7183.	.077	.8	.42	.50	4.98	.76	.07	553.
11	10.0	2.14	22.5	8.5	.76	5756.	.077	.8	.33	.16	1.73	.66	.06	443.
12	1.0	1.22	9.4	2.7	.16	1425.	.077	.1	.08	.09	.72	.21	.01	110.
13	.0	.87	7.2	3.9	.18	1198.	.077	.0	.07	.07	.55	.30	.01	92.
							TOTAL	47.5	19.4	3.2	56.7	190.7	4.0	25890.

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

EPA PNGV ENGINE EMISSION RESULTS PROJECT NO. 02-5137-434

ENGINE NUMBER
ENGINE MODEL 98 MB OM 611
ENGINE 2.2 L(134. CID) I4 CYL
ENGINE CYCLE DIESEL
ENGINE SERIAL DE 22 LA

TEST DMM 15-3E RUN
DATE 4/ 8/98 TIME
COMPUTER PROGRAM SSDIL 1.3 -R
CELL 4 BAG CART 1

DIESEL DMM15 EM-2568-F
HCR 2.06
C:.808 H:.140 O:.052 X:.000
ENGINE OIL
DENS. 6.818

MODE	TARGET SPEED RPM	TARGET LOAD PCT	TARGET TORQUE LB-FT	MEASURED TIME SEC	MEASURED SPEED RPM	MEASURED TORQUE LB-FT	C - B FUEL LB/HR	INTAKE AIR TEMP DEG F	INTAKE AIR HUMID G/KG	INTAKE AIR BARO IN-HG	FACTORS NOx HUM	FACTORS PART. HUM	FACTORS DRY WET	FACTORS F
1	4200.	0.	116.	300.	4200.	116.	39.7	74.0	8.2	28.96	.957	1.034	.972	1.009
2	4200.	0.	77.	300.	4200.	77.	30.1	74.0	7.7	28.96	.948	1.042	.979	1.008
3	3400.	0.	112.	300.	3400.	112.	29.0	74.0	7.5	28.96	.945	1.044	.979	1.008
4	2600.	0.	167.	300.	2600.	167.	29.8	74.0	7.5	28.97	.945	1.044	.980	1.008
5	2600.	0.	112.	300.	2600.	112.	20.9	74.0	7.6	28.97	.946	1.044	.980	1.008
6	2300.	0.	54.	300.	2300.	54.	10.1	74.0	7.7	28.97	.948	1.042	.986	1.008
7	2000.	0.	222.	300.	2000.	222.	30.9	75.0	7.9	28.97	.951	1.039	.977	1.011
8	2000.	0.	190.	300.	2000.	190.	25.7	75.0	7.9	28.97	.951	1.039	.980	1.011
9	2000.	0.	112.	300.	2000.	112.	15.6	74.0	7.8	28.97	.949	1.041	.983	1.008
10	2000.	0.	25.	600.	2000.	25.	5.2	74.0	7.9	28.97	.952	1.039	.986	1.008
11	1500.	0.	33.	600.	1500.	33.	4.7	75.0	8.0	28.97	.953	1.037	.990	1.011
12	900.	0.	2.	1200.	900.	2.	1.2	81.0	8.3	28.96	.959	1.033	.990	1.028
13	765.	0.	1.	1200.	765.	1.	.9	85.0	8.0	28.96	.953	1.037	.990	1.040

MODE	BHP FROM WORK	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2	WEIGHTED RESULTS MODE WF	POWER BHP	FUEL LB/HR	GRAMS/HOUR HC	GRAMS/HOUR CO	GRAMS/HOUR NOx	GRAMS/HOUR PART	GRAMS/HOUR CO2
1	93.0	6.85	56.7	484.6	11.30	53177.	.077	7.2	3.05	.53	4.37	37.27	.87	4091.
2	62.0	6.13	77.3	319.2	9.11	40337.	.077	4.8	2.32	.47	5.95	24.55	.70	3103.
3	73.0	3.79	46.5	352.1	4.88	38795.	.077	5.6	2.23	.29	3.58	27.09	.38	2984.
4	84.0	2.23	30.5	368.1	2.61	40010.	.077	6.5	2.30	.17	2.35	28.31	.20	3078.
5	56.0	2.69	38.3	168.6	4.57	27954.	.077	4.3	1.61	.21	2.95	12.97	.35	2150.
6	24.0	3.88	50.6	40.9	4.21	13467.	.077	1.8	.78	.30	3.89	3.15	.32	1036.
7	85.0	1.86	215.4	328.1	7.83	41158.	.077	6.5	2.38	.14	16.57	25.24	.60	3166.
8	73.0	1.73	86.6	304.9	3.52	34424.	.077	5.6	1.98	.13	6.66	23.46	.27	2648.
9	44.0	1.24	19.2	159.7	2.17	20973.	.077	3.4	1.20	.10	1.48	12.29	.17	1613.
10	10.0	7.18	68.7	10.1	1.13	6859.	.077	.8	.40	.55	5.28	.78	.09	528.
11	10.0	2.15	22.8	9.3	.90	6211.	.077	.8	.36	.17	1.75	.72	.07	478.
12	1.0	1.34	9.9	2.4	.16	1535.	.077	.1	.09	.10	.76	.19	.01	118.
13	.0	1.25	9.0	2.5	.14	1231.	.077	.0	.07	.10	.69	.19	.01	95.
							TOTAL	47.3	18.8	3.3	56.3	196.2	4.0	25087.

APPENDIX C

FULL-LOAD ENGINE TORQUE RAW DATA SHEETS

02-5137-434	2D-1
Project Number	Test Number

TORQUE MAP DATA SHEET

Cell 4 Date 2/13/98 Operator RDF

Speed Set ±25 rpm	1000	1500	2000	2600	3000
Start Time sec	0				
Torque ft-lbs	107.5	~~124~~ 183	227	229	217
Speed rpm	1000	1500	2000	2600	3000
Power hp	21	~~50~~ 53	87	114	125
Fuel Flow lb/hr	9.6	20.0	29.8	40.1	46.3
Water Out °F	189	192	192	195	195
Water In °F	156	169	161	176	172
Oil °F	171	172	188	203	208
Intake Air °F	75	75	75	73	74
Fuel °F	95	91	88	91	91
Exhaust (after turbo) °F	1024	1037	996	1117	1187
Intercooler In °F	160	186	260	264	263
Intercooler Out °F	112	94	91	102	109
Inlet Air Dewpoint °F	53.1	52.4	51.4	51.6	52.1
Chiller Water °F	56	56	56	56	56
Barometer "Hg	29.238	29.238	29.230	29.232	29.234
Inlet Air Restriction "H_2O	.22	-1.60	-4.86	-8.49	-10.40
Exhaust Restriction "Hg	.59	1.78	3.81	6.38	7.88
Boost Pres. Before IC "Hg	4.11	18.01	33.80	36.36	35.05
Boost Pres. After IC "Hg	4.05	17.67	33.17	35.29	33.70
Intercooler ΔP "H_2O	5.0	9.0	12.0	16.0	21.0
Oil Pressure psig	15	24	32	42	47
Fuel Pressure psig	.32	.42	.51	.64	.68
Engine Water Pres. psig	—	—	—	—	—
Hour Meter hours	2176.4	2176.4	2176.5	2176.6	2176.6
Tunnel Temp. °F	101	114	145	179	208
Exhaust after Cat. #2 1 °F	937	1001	931	1040	1097
Intake Mani. 2 °F	108	95	98	107	112
Exhaust before turbo 4 °F	903	1074	1113	1224	1273
Exhaust after Cat. #1 5 °F	996	1076	978	1097	1156
IC Coolant Supply 6 °F	78	78	78	76	75
Air before compressor 3 "H_2O	85	81	80	79	79
Exh. Before Turbo psig	1.0	8.5	18.0	23	25
Fuel Return "H_2O	.5	.5	.7	.7	1.0
Crankcase Vacuum "H_2O	0	1.5	.8	9.2	11.5
Main Vac. psig	29.2	29.2	29.2	29.2	29.2
~~Dewpoint °F~~					

02-5137-434	2D-1
Project Number	Test Number

TORQUE MAP DATA SHEET

Cell 4 Date 2/13/98 Operator RDF

Speed Set	±25 rpm	3500	4000	4200	4500	
Start Time	sec					
Torque	ft-lbs	185.5	161	152	80.5	
Speed	rpm	3500	4000	4200	4500	
Power	hp	125	124	122	70	
Fuel Flow	lb/hr	47.1	50.7	50.6	33.1	
Water Out	°F	194	196	196	193	
Water In	°F	167	173	172	161	
Oil	°F	205	197	194	198	
Intake Air	°F	73	72	72	72	
Fuel	°F	93	95	95	95	
Exhaust (after turbo)	°F	1162	1176	1179	896	
Intercooler In	°F	254	254	258	243	
Intercooler Out	°F	112	115	117	118	
Inlet Air Dewpoint	°F	52.4	52.4	53.0	53.0	
Chiller Water	°F	56	56	57	56	
Barometer	"Hg	29.230	29.232	29.233	29.233	
Inlet Air Restriction	"H_2O	-12.93	-15.18	-16.51	-15.83	
Exhaust Restriction	"Hg	9.18	10.49	11.16	9.06	
Boost Pres. Before IC	"Hg	31.68	30.61	30.59	26.70	
Boost Pres. After IC	"Hg	29.83	28.52	28.35	24.51	
Intercooler ΔP	"H_2O	29.0	30.0	33.0	35.0	
Oil Pressure	psig	50	50	50	50	
Fuel Pressure	psig	.76	.84	.87	.92	
Engine Water Pres.	psig	—	—	—	—	
Hour Meter	hours	2176.7	2176.8	2176.8	2176.9	
Tunnel Temp.	°F	224	240	250	226	
Exhaust after Cat. #2 1	°F	1067	1098	1101	831	
Intake Mani. 2	°F	114	117	119	116	
Exhaust before turbo 4	°F	1224	1246	1245	955	
Exhaust after Cat. #1 5	°F	1113	1141	1141	850	
IC Coolant Supply 6	°F	74	74	73	73	
Air before compressor 3	"H_2O	78	78	78	78	
Exh. Before Turbo	psig	27	29.5	31	30	
Fuel Return	"H_2O	1.3	1.3	1.5	1.8	
Crankcase Vacuum	"H_2O	13.5	14.0	15.0	14.5	
Main Vac.	psig	29.2	29.2	29.2	29.2	
~~Dewpoint~~	~~°F~~					

02-5137-434		FT20-1
Project Number		Test Number

TORQUE MAP DATA SHEET

Cell 4 Date 2/17/98 Operator RDF

Speed Set	±25 rpm	1000	1500	2000	2600	3000
Start Time	sec	0				
Torque	ft-lbs	104	180	225	227	215.5
Speed	rpm	1000	1500	2000	2600	3000
Power	hp	20	52	86	113	124
Fuel Flow	lb/hr	9.4	19.1	28.7	39.3	44.4
Water Out	°F	187	187	192	194	195
Water In	°F	142	147	160	172	174
Oil	°F	192	201	185	198	200
Intake Air	°F	73	75	75	75	75
Fuel	°F	97	94	94	94	96
Exhaust (after turbo)	°F	1005	1005	979	1106	1178
Intercooler In	°F	157	176	254	269	265
Intercooler Out	°F	105	89	83	96	106
Inlet Air Dewpoint	°F	52.0	51.4	50.9	51.0	51.4
Chiller Water	°F	56	56	56	56	56
Barometer	"Hg	28.939	28.941	28.941	28.944	28.948
Inlet Air Restriction	"H_2O	.24	-1.52	-4.89	-8.58	-10.48
Exhaust Restriction	"Hg	.60	1.76	3.81	6.47	7.97
Boost Pres. Before IC	"Hg	4.07	17.56	33.80	36.60	35.42
Boost Pres. After IC	"Hg	3.96	17.24	33.13	35.51	33.91
Intercooler ΔP	"H_2O	5.0	8.0	12.0	16.5	21.0
Oil Pressure	psig	15	24	32	41	46
Fuel Pressure	psig	.31	.41	.53	.63	.68
Engine Water Pres.	psig	—	—	—	—	—
Hour Meter	hours	2182.2	2182.3	2182.4	2182.4	2182.5
Tunnel Temp.	°F	105	116	146	183	209
Exhaust after Cat. #2 1	°F	948	995	914	1032	1082
Intake Mani. 2	°F	102	87	90	102	107
Exhaust before turbo 4	°F	878	1051	1097	1215	1256
Exhaust after Cat. #1 5	°F	1021	1071	963	1091	1141
IC Coolant Supply 6	°F	68	68	68	69	69
Air before compressor 3	"H_2O	84	79	78	79	78
Exh. Before Turbo	psig	1.0	8.0	18.0	23.0	25.0
Fuel Return	"H_2O	2.4	2.6	2.8	3.2	3.6
Crankcase Vacuum	"H_2O	0	1.2	5.0	9.5	11.8
Main Vac.	psig	28.0	29.0	29.0	29.0	29.0
~~Dewpoint~~	~~°F~~					

PAGE 1 of 2

02-5137-434	FT20-1
Project Number	Test Number

TORQUE MAP DATA SHEET

Cell 4 Date 2/17/98 Operator RDF

Speed Set ±25	rpm	3500	4000	4200	4500	
Start Time	sec					
Torque	ft-lbs	186	162	153	85	
Speed	rpm	3500	4000	4200	4500	
Power	hp	125	125	123	74	
Fuel Flow	lb/hr	45.8	48.9	50.7	34.4	
Water Out	°F	195	196	197	196	
Water In	°F	170	174	172	174	
Oil	°F	208	200	199	203	
Intake Air	°F	74	74	74	74	
Fuel	°F	97	98	99	100	
Exhaust (after turbo)	°F	1149	1171	1180	933	
Intercooler In	°F	258	259	263	251	
Intercooler Out	°F	109	114	118	121	
Inlet Air Dewpoint	°F	52.0	52.0	52.1	52.0	
Chiller Water	°F	56	56	56	56	
Barometer	"Hg	28.951	28.953	28.953	28.953	
Inlet Air Restriction	"H_2O	-13.14	-15.35	-16.58	-15.94	
Exhaust Restriction	"Hg	9.26	10.56	11.20	9.30	
Boost Pres. Before IC	"Hg	33.02	30.87	30.84	27.14	
Boost Pres. After IC	"Hg	30.16	28.77	28.61	24.69	
Intercooler ΔP	"H_2O	29.0	30	32	34	
Oil Pressure	psig	RF ~~59~~ 49	50	50	50	
Fuel Pressure	psig	.73	.76	.79	.84	
Engine Water Pres.	psig	—	—	—	—	
Hour Meter	hours	2182.6	2182.7	2182.7	2182.8	
Tunnel Temp.	°F	225	241	252	231	
Exhaust after Cat. #2 1	°F	1057	1095	1100	848	
Intake Mani. 2	°F	111	117	119	117	
Exhaust before turbo 4	°F	1212	1243	1247	975	
Exhaust after Cat. #1 5	°F	1102	1137	1141	868	
IC Coolant Supply 6	°F	70	70	71	71	
Air before compressor 3	"H_2O	78	78	78	78	
Exh. Before Turbo	psig	27.5	29.5	31.5	30	
Fuel Return	"H_2O	4.0	4.4	4.6	4.3	
Crankcase Vacuum	"H_2O	13.8	14.5	RF ~~12~~ 14.5	14.5	
Main Vac.	psig	29.0	29.0	29.0	29.0	
~~Dewpoint~~	~~°F~~					

PAGE 2 of 2

02-5137-434	FT 100-1
Project Number	Test Number

TORQUE MAP DATA SHEET

Cell 4 Date 2/17/98 Operator RDF

Speed Set	±25 rpm	1000	1500	2000	2600	3000
Start Time	sec	0				
Torque	ft-lbs	103	169	220	224	
Speed	rpm	1000	1500	2000	2600	3000
Power	hp	20	49	85	111	
Fuel Flow	lb/hr	8.6	17.6	27.8	38.4	
Water Out	°F	190	193	190	193	190
Water In	°F	155	174	162	168	164
Oil	°F	187	200	196	203	209
Intake Air	°F	75	75	74	74	74
Fuel	°F	98	95	95	96	100
Exhaust (after turbo)	°F	1011	985	972	1094	1166
Intercooler In	°F	165	167	252	269	267
Intercooler Out	°F	109	97	88	101	109
Inlet Air Dewpoint	°F	53.1	52.4	51.6	51.4	52.0
Chiller Water	°F	56	56	56	56	56
Barometer	"Hg	28.915	28.912	28.912	28.916	28.916
Inlet Air Restriction	"H_2O	.11	-1.39	-4.69	-8.45	-10.49
Exhaust Restriction	"Hg	.59	1.57	3.71	6.34	7.87
Boost Pres. Before IC	"Hg	3.83	15.42	33.23	36.58	35.33
Boost Pres. After IC	"Hg	3.73	15.14	32.59	35.48	33.92
Intercooler ΔP	"H_2O	5.0	8.0	12.0	17.0	21.0
Oil Pressure	psig	15	24	32	42	47
Fuel Pressure	psig	.31	.42	.54	.65	.71
~~Engine Water Pres.~~	~~psig~~	—	—	—	—	—
Hour Meter	hours	2183.3	2183.4	2183.4	2183.5	2183.5
Tunnel Temp.	°F	102	113	144	180	207
Exhaust after Cat. #2 1	°F	940	966	916	1020	1071
Intake Mani. 2	°F	110	97	96	106	111
Exhaust before turbo 4	°F	895	1024	1096	1206	1245
Exhaust after Cat. #1 5	°F	1004	1050	965	1084	1131
IC Coolant Supply 6	°F	74	73	72	73	80
Air before compressor 3	"H_2O	89	82	81	80	73
Exh. Before Turbo	psig	1.0	7.5	18.0	23.0	25.0
Fuel Return	"H_2O	4.1	4.1	4.4	4.5	5.0
Crankcase Vacuum	"H_2O	0	1.2	4.9	9.5	11.5
Main Vac.	psig	29.0	29.0	29.0	29.0	29.0
~~Dewpoint~~	~~°F~~					

PAGE 1 of 2

02-5137-434	FT100-1
Project Number	Test Number

TORQUE MAP DATA SHEET

Cell 4 Date 2/17/98 Operator RDF

Speed Set	±25 rpm	3500	4000	4200	4500	
Start Time	sec					
Torque	ft-lbs	184.5	161.0	152	78.5	
Speed	rpm	3500	4000	4200	4500	
Power	hp	124	123	122	68	
Fuel Flow	lb/hr	45.6	48.7	RF ~~4~~51.5	32.1	
Water Out	°F	194	196	193	197	
Water In	°F	169	171	165	167	
Oil	°F	206	202	200	205	
Intake Air	°F	74	74	73	73	
Fuel	°F	102	102	103	104	
Exhaust (after turbo)	°F	1138	1168	1173	908	
Intercooler In	°F	258	259	264	250	
Intercooler Out	°F	113	117	121	123	
Inlet Air Dewpoint	°F	52.0	52.1	52.1	52.1	
Chiller Water	°F	56	56	56	56	
Barometer	"Hg	28.917	28.919	28.921	28.920	
Inlet Air Restriction	"H_2O	-13.02	-15.22	-16.52	-15.75	
Exhaust Restriction	"Hg	9.10	10.44	11.10	9.00	
Boost Pres. Before IC	"Hg	32.05	30.89	30.84	27.04	
Boost Pres. After IC	"Hg	30.15	28.79	28.56	24.60	
Intercooler ΔP	"H_2O	29	30	32	34	
Oil Pressure	psig	49	50	49	50	
Fuel Pressure	psig	.76	.83	.84	.91	
~~Engine Water Pres.~~	~~psig~~	—	—	—	—	
Hour Meter	hours	2183.6	2183.7	2183.7	2183.8	
Tunnel Temp.	°F	222	240	251	227	
Exhaust after Cat. #2 1	°F	1049	1089	1092	817	
Intake Mani. 2	°F	116	120	122	120	
Exhaust before turbo 4	°F	1204	1236	1239	948	
Exhaust after Cat. #1 5	°F	1097	1134	1136	838	
IC Coolant Supply 6	°F	73	74	75	75	
Air before compressor 3	"H_2O	79	79	79	79	
Exh. Before Turbo	psig	27	29.5	31	30	
Fuel Return	"H_2O	5.3	5.5	5.7	5.0	
Crankcase Vacuum	"H_2O	13.5	14.3	15.0	14.0	
Main Vac.	psig	29.0	29.0	29.0	29.0	
~~Dewpoint~~	~~°F~~					

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SWED-1
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TORQUE MAP DATA SHEET

Cell 4 Date 2/18/98 Operator RDF

Speed Set ±25 rpm	1000	1500	2000	2600	3000
Start Time sec	0				
Torque ft-lbs	103.5	177	223	226.5	213
Speed rpm	1000	1500	2000	2600	3000
Power hp	20	51	85	113	123
Fuel Flow lb/hr	10.8	19.2	28.9	39.6	44.8
Water Out °F	188	192	196	194	195
Water In °F	144	163	178	173	171
Oil °F	173	160	187	207	209
Intake Air °F	73	74	74	74	73
Fuel °F	98	95	95	97	97
Exhaust (after turbo) °F	1029	1057	988	1104	1181
Intercooler In °F	163	195	252	268	265
Intercooler Out °F	110	86	86	97	108
Inlet Air Dewpoint °F	53.7	52.4	52.1	52.0	52.0
Chiller Water °F	55	56	56	56	56
Barometer "Hg	28.924	28.920	28.920	28.920	28.916
Inlet Air Restriction "H_2O	.22	-1.60	-4.83	-8.64	-10.54
Exhaust Restriction "Hg	.59	1.83	3.80	6.42	7.97
Boost Pres. Before IC "Hg	4.02	17.75	33.64	36.60	35.39
Boost Pres. After IC "Hg	3.85	17.27	32.84	35.44	33.94
Intercooler ΔP "H_2O	5.0	8.0	12.0	16.5	21
Oil Pressure psig	15	23	32	41	46
Fuel Pressure psig	.14	.18	.27	.37	.44
~~Engine Water Pres. psig~~	—	—	—	—	—
Hour Meter hours	2188.3	2188.4	2188.4	2188.5	2188.6
Tunnel Temp. °F	103	117	146	179	208
Exhaust after Cat. #2 °F	—	1003	924	1030	1088
Intake Mani. °F	108	90	93	104	111
Exhaust before turbo °F	801	1069	1105	1220	1265
Exhaust after Cat. #1 °F	1024	1079	975	1097	1150
IC Coolant Supply °F	75	73	73	74	74
Air before compressor "H_2O	84	81	80	78	78
Exh. Before Turbo psig	1.0	8.0	18.0	23.0	25.0
Fuel Return "H_2O	3.7	4.0	4.2	4.5	4.8
Crankcase Vacuum "H_2O	0	1.5	5.0	9.5	11.5
Main Vac. psig	29.0	29.0	29.0	29.0	29.0
~~Dewpoint °F~~					

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Project Number	Test Number

TORQUE MAP DATA SHEET

Cell 4 Date 2/18/98 Operator RDF

Speed Set ±25	rpm	3500	4000	4200	4500	
Start Time	sec					
Torque	ft-lbs	185.0	161.0	151.5	81.0	
Speed	rpm	3500	4000	4200	4500	
Power	hp	124	124	122	71	
Fuel Flow	lb/hr	49.3	48.9	51.5	35.2	
Water Out	°F	195	196	197	196	
Water In	°F	173	173	173	172	
Oil	°F	211	200	199	205	
Intake Air	°F	73	72	72	72	
Fuel	°F	99	98	99	99	
Exhaust (after turbo)	°F	1161	1179	1185	961	
Intercooler In	°F	258	259	264	252	
Intercooler Out	°F	112	116	120	123	
Inlet Air Dewpoint	°F	52.4	52.4	52.4	52.7	
Chiller Water	°F	56	56	56	56	
Barometer	"Hg	28.904	28.903	28.905	28.904	
Inlet Air Restriction	"H_2O	-13.04	-15.29	-16.54	-15.84	
Exhaust Restriction	"Hg	9.26	10.55	11.22	9.45	
Boost Pres. Before IC	"Hg	32.10	30.91	30.84	27.13	
Boost Pres. After IC	"Hg	30.14	28.72	28.50	24.58	
Intercooler ΔP	"H_2O	29	30	32	34	
Oil Pressure	psig	59	50	49	50	
Fuel Pressure	psig	~~5.1~~ (.47)	.53	.56	.61	
~~Engine Water Pres.~~	~~psig~~	—	—	—	—	
Hour Meter	hours	2188.6	2188.7	2188.7		
Tunnel Temp.	°F	226	242	253	234	
Exhaust after Cat. #2	°F	1064	1096	1104	860	
Intake Mani.	°F	115	119	122	120	
Exhaust before turbo	°F	1219	1245	1250	986	
Exhaust after Cat. #1	°F	1112	1142	1147	877	
IC Coolant Supply	°F	74	74	75	75	
Air before compressor	"H_2O	78	78	78	78	
Exh. Before Turbo	psig	27.0	30.0	31.0	30.0	
Fuel Return	"H_2O	5.1	5.5	5.6	6.0	
Crankcase Vacuum	"H_2O	13.5	14.1	15.0	14.5	
Main Vac.	psig	29.0	29.0	29.0	29.0	
~~Dewpoint~~	~~°F~~					

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Project Number		Test Number

TORQUE MAP DATA SHEET

Cell 4 Date 2/19 Operator RDF

Speed Set	±25 rpm	1000	1500	2000	2600	3000
Start Time	sec	0				
Torque	ft-lbs	104.0	174.0	222	225.5	213.5
Speed	rpm	1000	1500	2000	2600	3000
Power	hp	20	50	85	112	122
Fuel Flow	lb/hr	9.2	19.1	29.9	40.6	46.5
Water Out	°F	188	189	191	192	193
Water In	°F	146	147	159	162	167
Oil	°F	189	172	186	203	209
Intake Air	°F	74	74	75	73	73
Fuel	°F	104	100	101	101	101
Exhaust (after turbo)	°F	1034	1043	987	1087	1151
Intercooler In	°F	166	192	258	268	265
Intercooler Out	°F	116	87	90	101	111
Inlet Air Dewpoint	°F	52.7	49.9	48.8	48.4	49.5
Chiller Water	°F	55	54	53	53	54
Barometer	"Hg	29.069	29.070	29.070	29.072	29.072
Inlet Air Restriction	"H_2O	0	-1.53	-4.66	-8.49	-10.43
Exhaust Restriction	"Hg	.58	1.74	3.67	6.28	7.74
Boost Pres. Before IC	"Hg	3.63	16.62	32.72	36.52	35.27
Boost Pres. After IC	"Hg	3.53	16.23	32.02	35.43	33.83
Intercooler ΔP	"H_2O	5.0	8.0	12.0	16.5	21.0
Oil Pressure	psig	16.0	23	31	41	46
Fuel Pressure	psig	.11	.14	.23	.33	.39
~~Engine Water Pres.~~	~~psig~~	~~83~~	—	—	—	—
Hour Meter	hours	2194.1	2194.3	2194.4	2194.5	2194.5
Tunnel Temp.	°F	104	115	144	176	200
Exhaust after Cat. #2	°F	946	986	920	1014	1066
Intake Mani.	°F	115	92	99	109	115
Exhaust before turbo	°F	913	1055	1100	1199	1239
Exhaust after Cat. #1	°F	1021	1055	973	1076	1126
IC Coolant Supply	°F	75	74	74	75	75
Air before compressor	"H_2O	-83	83	81	80	79
Exh. Before Turbo	psig	1.0	8.0	17.0	22.5	25.0
Fuel Return	"H_2O	3.0	3.6	3.9	3.9	4.0
Crankcase Vacuum	"H_2O	0	1.2	4.6	9.5	11.5
Main Vac.	psig	29.1	29.1	29.1	29.2	29.2
~~Dewpoint~~	~~°F~~					

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Project Number	Test Number

TORQUE MAP DATA SHEET

Cell 4 Date 2/19/98 Operator RDF

Speed Set	±25 rpm	3500	4000	4200	4500	
Start Time	sec					
Torque	ft-lbs	184.5	162	152.5	84.5	
Speed	rpm	3500	4000	4200	4500	
Power	hp	124	124	123	73	
Fuel Flow	lb/hr	46.4	52.3	51.6	36.5	
Water Out	°F	195	196	196	194	
Water In	°F	173	171	172	166	
Oil	°F	214	204	200	206	
Intake Air	°F	73	73	73	73	
Fuel	°F	100	101	101	102	
Exhaust (after turbo)	°F	1137	1157	1166	913	
Intercooler In	°F	257	257	261	248	
Intercooler Out	°F	116	120	123	125	
Inlet Air Dewpoint	°F	50.0	50.3	50.6	50.6	
Chiller Water	°F	54	54	54	54	
Barometer	"Hg	29.073	29.073	29.072	29.073	
Inlet Air Restriction	"H_2O	-12.84	-14.99	-16.37	-15.69	
Exhaust Restriction	"Hg	9.00	10.27	10.94	9.02	
Boost Pres. Before IC	"Hg	31.93	30.80	30.75	26.97	
Boost Pres. After IC	"Hg	30.02	28.65	28.41	24.69	
Intercooler ΔP	"H_2O	29.0	30	32	34.5	
Oil Pressure	psig	49	50	49	50	
Fuel Pressure	psig	.47	.56	.60	.63	
~~Engine Water Pres.~~	~~psig~~	—	—	—	—	
Hour Meter	hours	2194.6	2194.6	2194.7	2194.8	
Tunnel Temp.	°F	221	235	247	225	
Exhaust after Cat. #2	°F	1041	1082	1085	833	
Intake Mani.	°F	120	123	125	122	
Exhaust before turbo	°F	1196	1227	1230	959	
Exhaust after Cat. #1	°F	1091	1128	1129	851	
IC Coolant Supply	°F	75	76	75	76	
Air before compressor	"H_2O	78	78	78	78	
Exh. Before Turbo	psig	27.0	29.5	31	30	
Fuel Return	"H_2O	4.2	4.3	4.3	4.5	
Crankcase Vacuum	"H_2O	13.5	14.0	15.0	14.4	
Main Vac.	psig	29.2	29.2	29.2	29.2	
~~Dewpoint~~	~~°F~~					

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Project Number	Test Number

TORQUE MAP DATA SHEET

Cell 4 Date 2/20/98 Operator RDF

Speed Set ±25 rpm	1000	1500	2000	2600	3000
Start Time sec	0				
Torque ft-lbs	104.5	158	223	230.5	217.5
Speed rpm	1000	1500	2000	2600	3000
Power hp	20	45	85	115	125
Fuel Flow lb/hr	—	—	—	—	—
Water Out °F	189	185	188	191	193
Water In °F	154	135	151	160	165
Oil °F	191	201	200	207	213
Intake Air °F	73	72	73	73	73
Fuel °F	99	99	96	100	103
Exhaust (after turbo) °F	1030	960	985	1069	1143
Intercooler In °F	161	150	232	266	265
Intercooler Out °F	111	99	89	99	109
Inlet Air Dewpoint °F	53.5	53.0	52.4	50.9	51.4
Chiller Water °F	56	56	55	55	55
Barometer "Hg	29.105	29.103	29.101	29.098	29.096
Inlet Air Restriction "H_2O	0	-1.22	-4.44	-8.50	-10.46
Exhaust Restriction "Hg	.6	1.39	3.57	6.22	7.68
Boost Pres. Before IC "Hg	3.51	11.99	31.42	36.50	35.24
Boost Pres. After IC "Hg	3.38	11.73	30.73	35.33	33.76
Intercooler ΔP "H_2O	5.0	7.0	12.0	17.0	21.0
Oil Pressure psig	17	25	32	41	46
Fuel Pressure psig	0	.06	.11	.20	.24
~~Engine Water Pres psig~~	~~4-4.5~~	—	—	—	—
Hour Meter hours	2200.0	2200.0	2200.1	2200.1	2200.2
Tunnel Temp. °F	104	112	141	177	200
Exhaust after Cat. #2 °F	959	941	929	1000	1058
Intake Mani. °F	110	100	96	107	113
Exhaust before turbo °F	901	991	1094	1180	1228
Exhaust after Cat. #1 °F	1020	1021	978	1057	1118
IC Coolant Supply °F	76	76	76	76	76
Air before compressor "H_2O	87	83	81	80	80
Exh. Before Turbo psig	1.0	6.5	16.0	22.5	25.0
Fuel Return "H_2O	4-4.8	5.0	4-5	4-5	4-6
Crankcase Vacuum "H_2O	0	1.0	9.0	9.0	11.5
Main Vac. psig	29.2	29.2	29.2	29.2	29.2
~~Dewpoint °F~~					

02-5137-434	DMM15-1
Project Number	Test Number

TORQUE MAP DATA SHEET

Cell 4 Date 2/20/98 Operator RDF

Speed Set ±25	rpm	3500	4000	4200	4500	
Start Time	sec					
Torque	ft-lbs	193	172.0	164.0	90.0	
Speed	rpm	3500	4000	4200	4500	
Power	hp	130	132	132	77	
Fuel Flow	lb/hr	—	—	—	—	
Water Out	°F	193	196	193	196	
Water In	°F	165	169	169	171	
Oil	°F	212	201	204	201	
Intake Air	°F	73	73	73	73	
Fuel	°F	105	105	104	104	
Exhaust (after turbo)	°F	1183	1223	1253	981	
Intercooler In	°F	~~11~~ 257	258	262	249	
Intercooler Out	°F	114	118 80.9	121	123	
Inlet Air Dewpoint	°F	51.0	RF ~~80~~ 54	50.6	50.3	
Chiller Water	°F	54	54	54	54	
Barometer	"Hg	29.094	29.092	29.091	29.092	
Inlet Air Restriction	"H_2O	-12.86	-14.99	-16.28	-15.70	
Exhaust Restriction	"Hg	9.28	10.75	11.57	9.31	
Boost Pres. Before IC	"Hg	31.85	30.75	30.69	26.93	
Boost Pres. After IC	"Hg	29.91	28.59	28.37	24.42	
Intercooler ΔP	"H_2O	28.0	30.0	32.0	34.0	
Oil Pressure	psig	49	49	49	50	
Fuel Pressure	psig	.28	.35	.37	.43	
~~Engine Water Pres.~~	psig	—	—	—	—	
Hour Meter	hours	2200.2	2200.3	2200.3	2200.4	
Tunnel Temp.	°F	224	247	262	235	
Exhaust after Cat. #2	°F	1098	1150	1173	857	
Intake Mani.	°F	118	121	124	121	
Exhaust before turbo	°F	1248	1289	1311	992	
Exhaust after Cat. #1	°F	1149	1195	1215	887	
IC Coolant Supply	°F	76	76	76	76	
Air before compressor	"H_2O	79	79	79	78	
Exh. Before Turbo	psig	27.0	29.0	31.0	30.0	
Fuel Return	"H_2O	5-6	5-7	5-8	7-8	
Crankcase Vacuum	"H_2O	13.6	RF ~~8~~ 14.2	15.0	14.5	
Main Vac.	psig	29.2	29.2	29.2	29.2	
~~Dewpoint~~	~~°F~~					

APPENDIX D

GRAPHS OF AVERAGE EMISSION RESULTS FOR INDIVIDUAL MODES AND COMPOSITE MODE

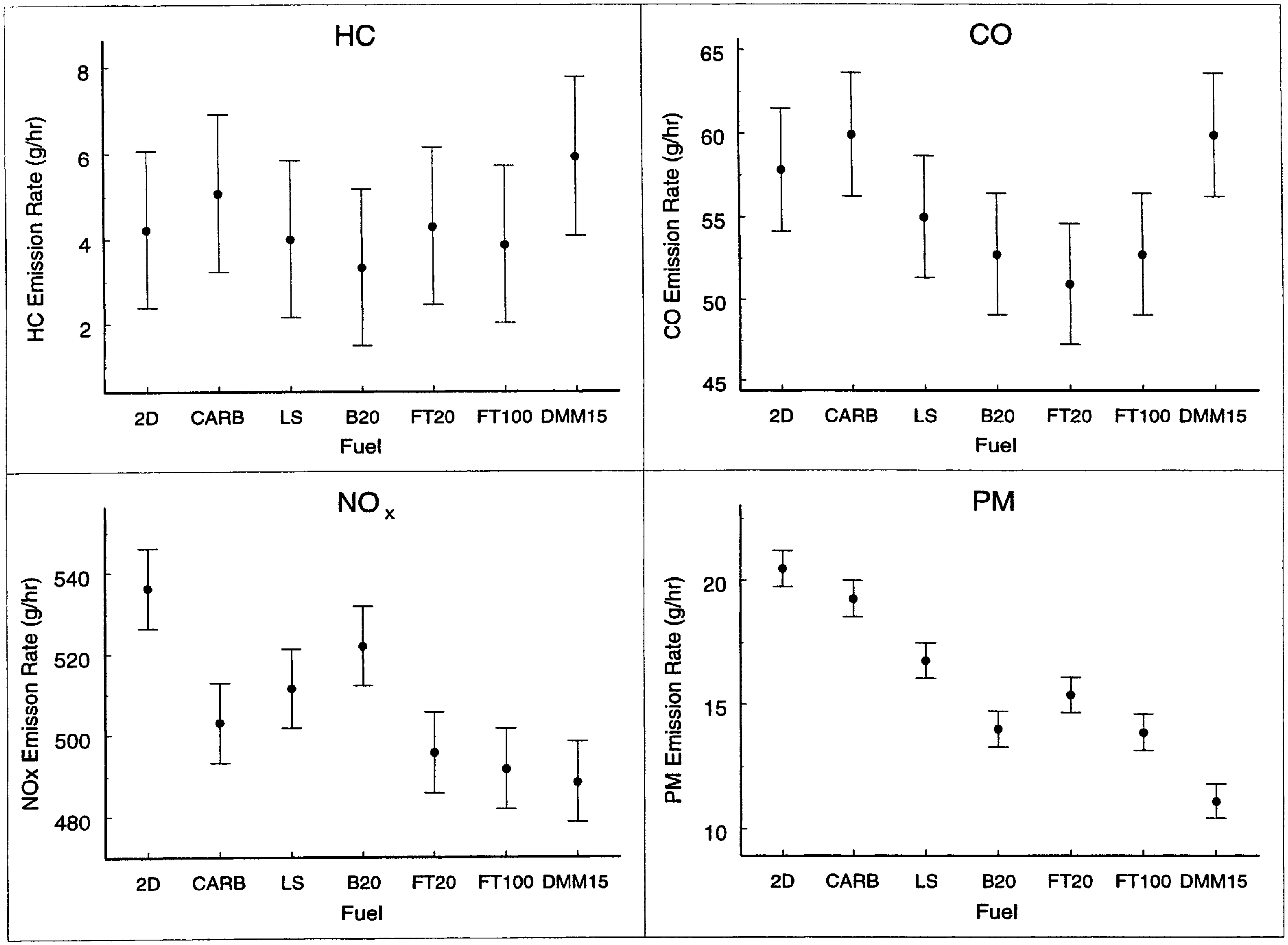

FIGURE D-1. MODE 1 EXHAUST EMISSION RATES, WITH 95 PERCENT CONFIDENCE INTERVALS

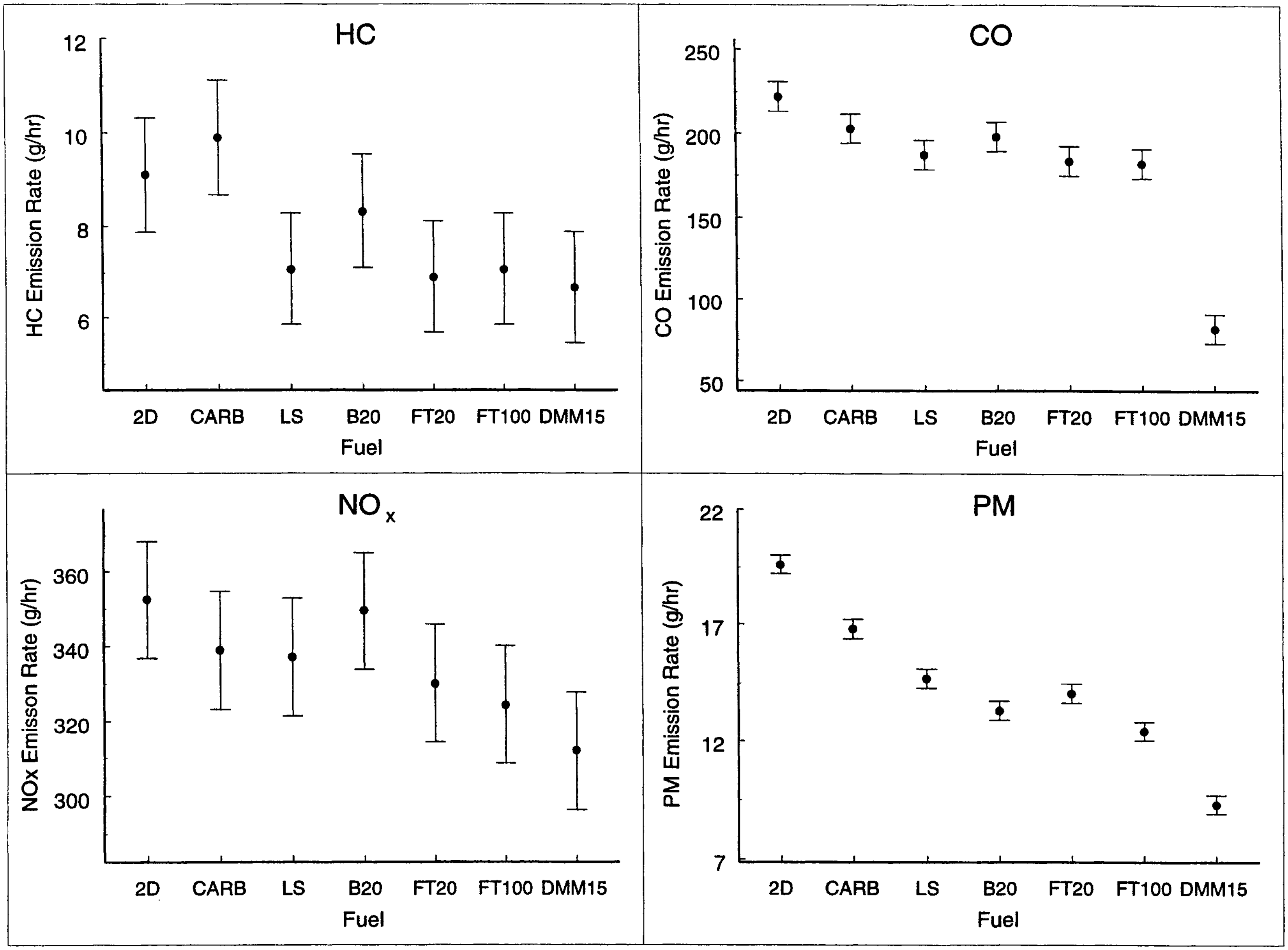

FIGURE D-2. MODE 2 EXHAUST EMISSION RATES, WITH 95 PERCENT CONFIDENCE INTERVALS

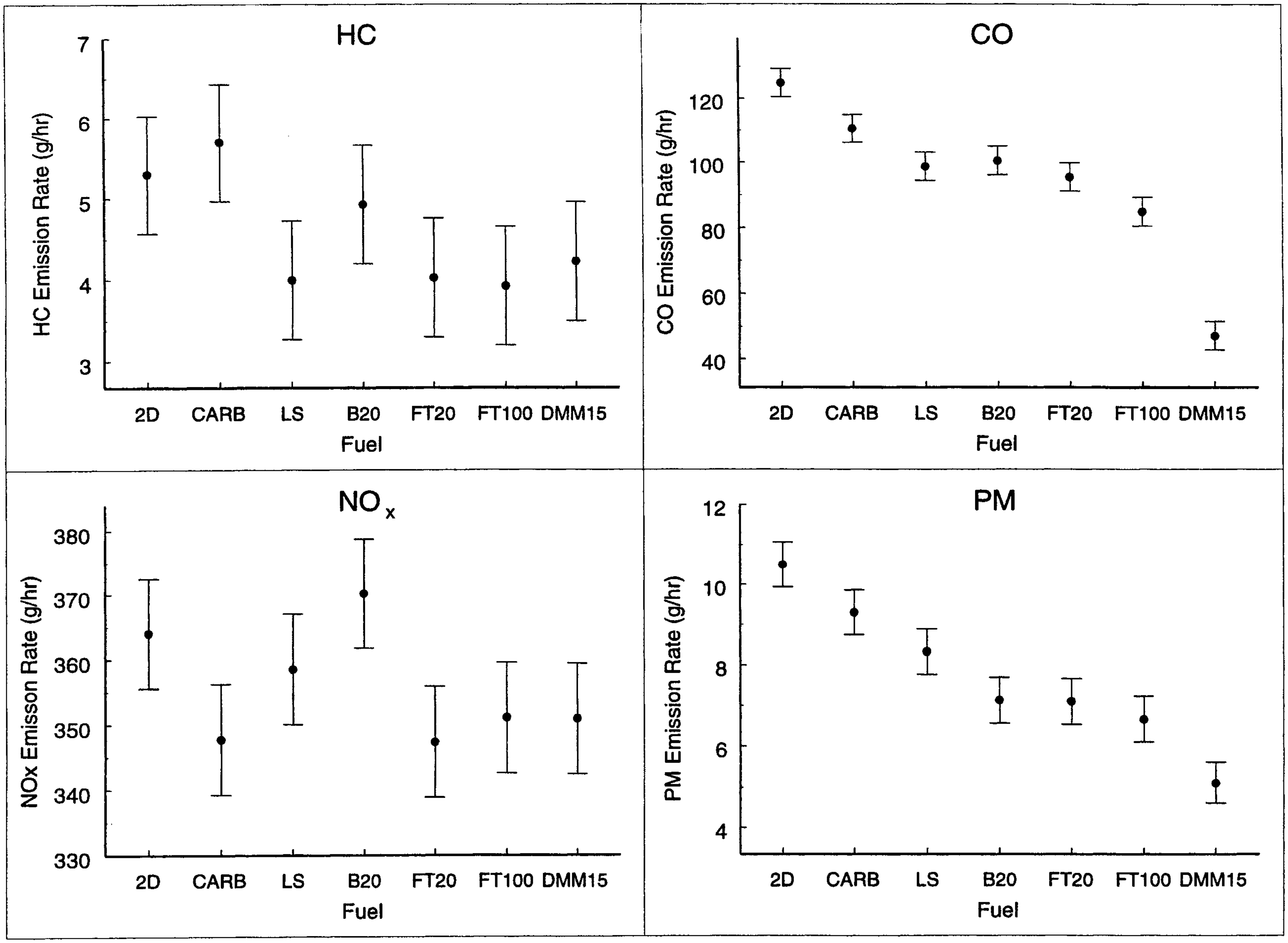

FIGURE D-3. MODE 3 EXHAUST EMISSION RATES, WITH 95 PERCENT CONFIDENCE INTERVALS

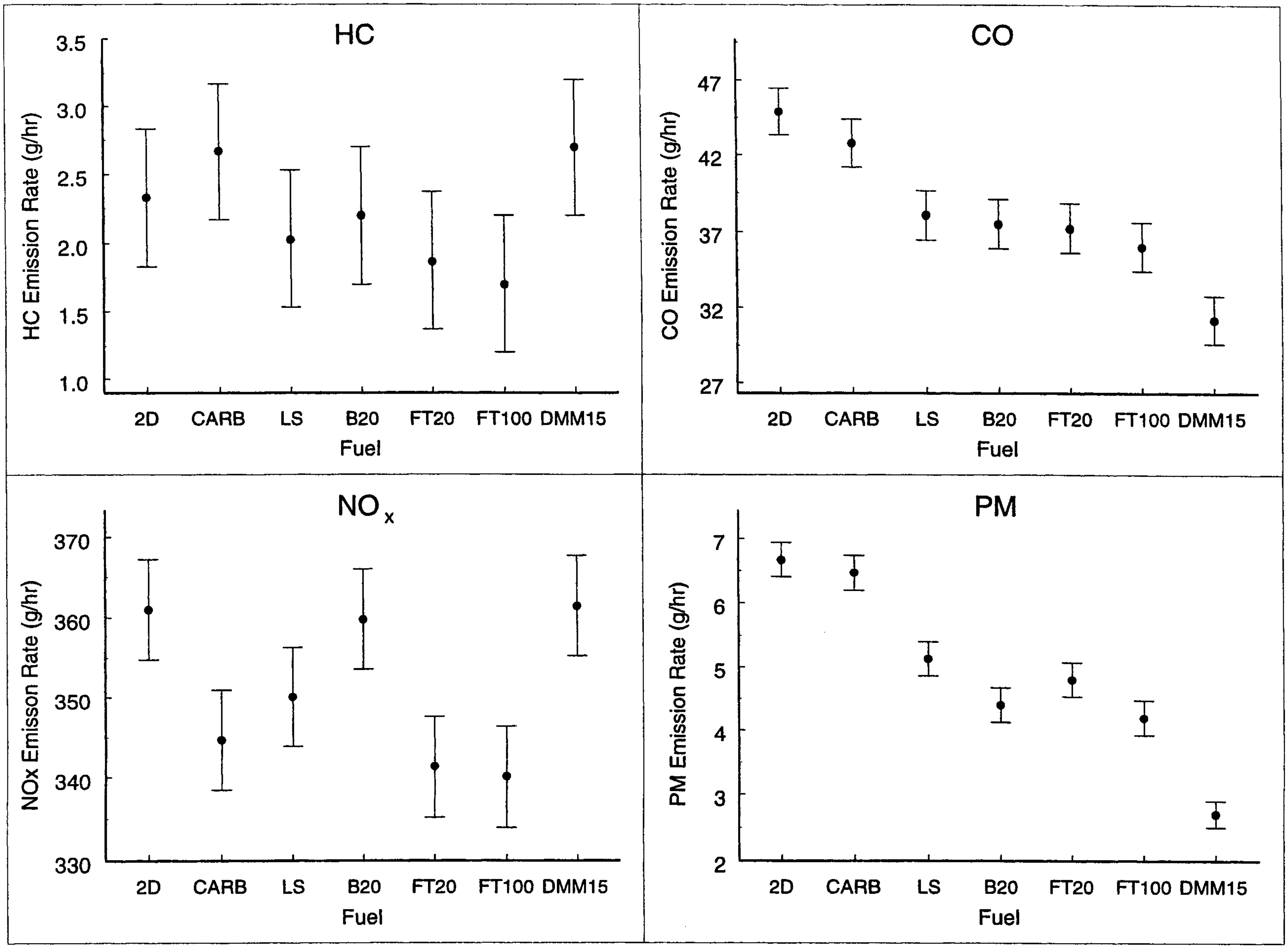

FIGURE D-4. MODE 4 EXHAUST EMISSION RATES, WITH 95 PERCENT CONFIDENCE INTERVALS

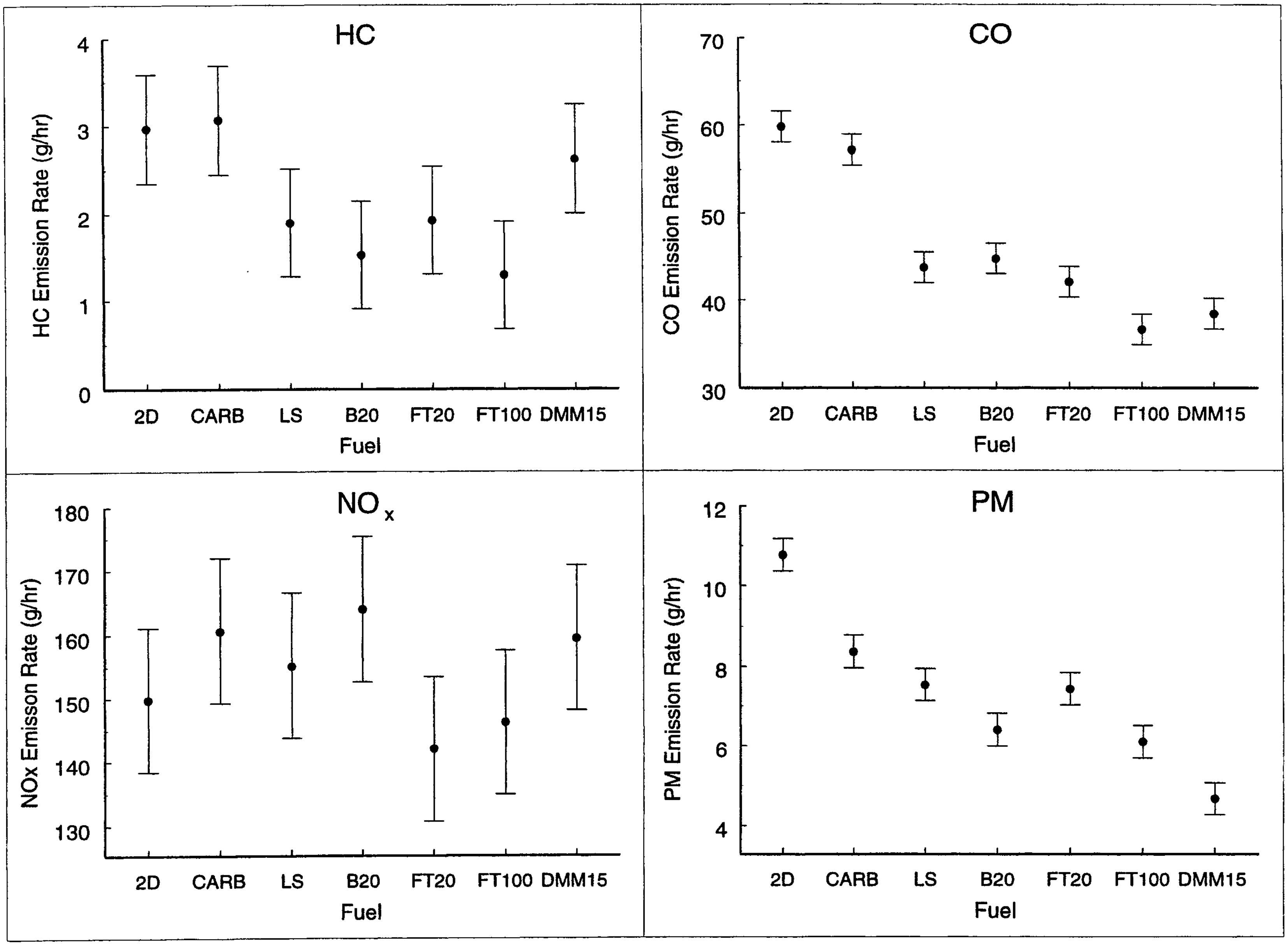

FIGURE D-5. MODE 5 EXHAUST EMISSION RATES, WITH 95 PERCENT CONFIDENCE INTERVALS

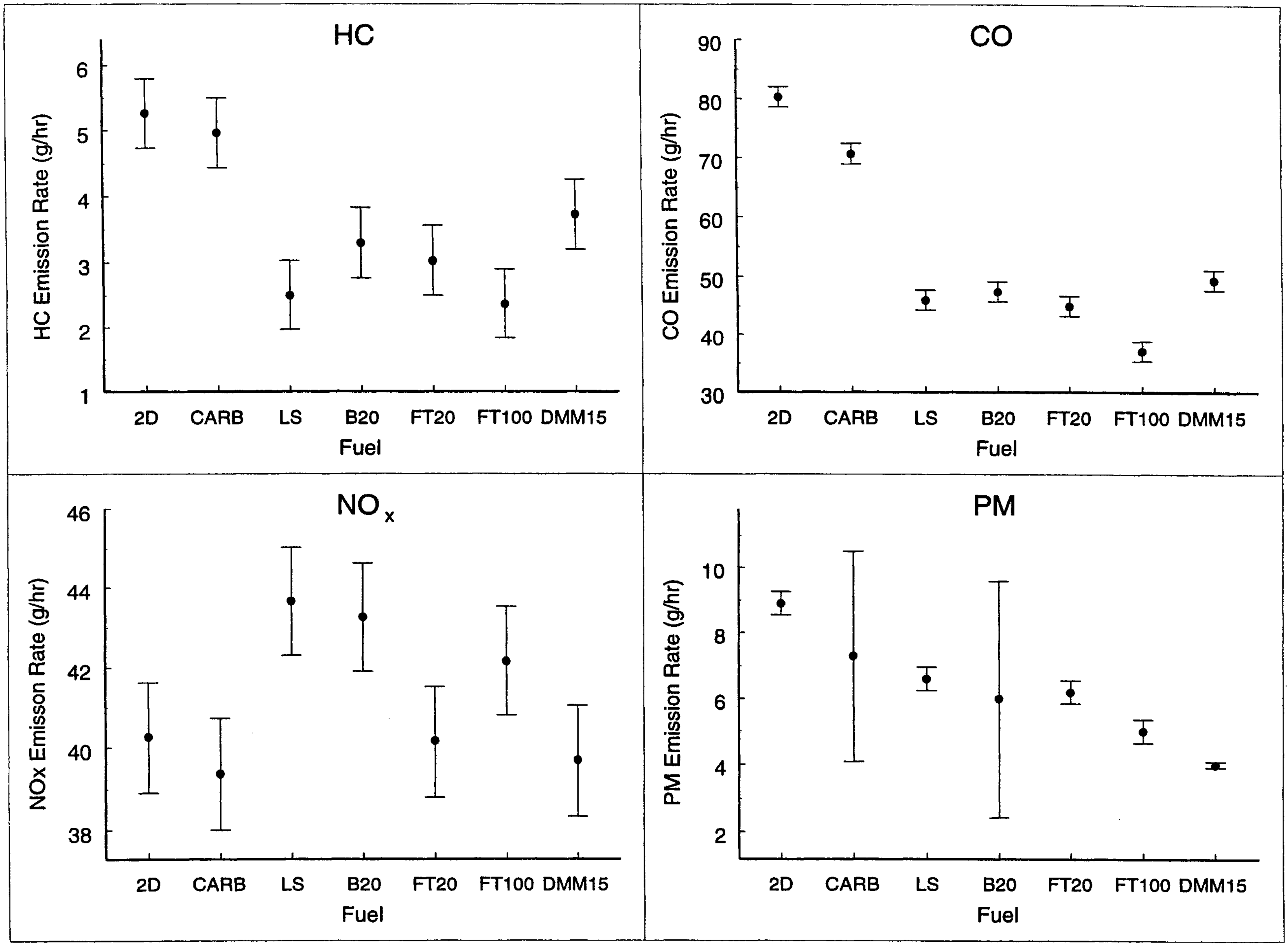

FIGURE D-6. MODE 6 EXHAUST EMISSION RATES, WITH 95 PERCENT CONFIDENCE INTERVALS

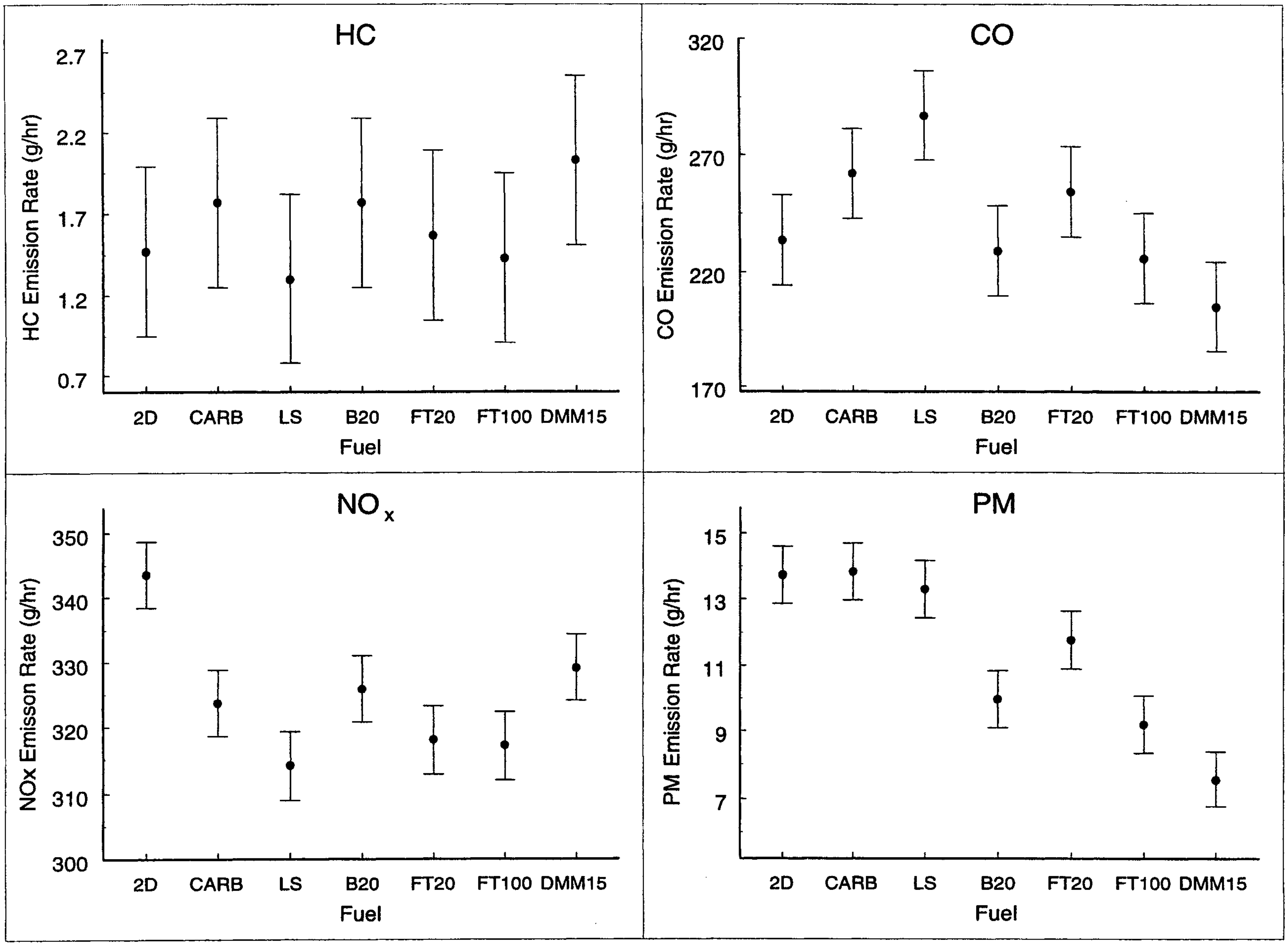

FIGURE D-7. MODE 7 EXHAUST EMISSION RATES, WITH 95 PERCENT CONFIDENCE INTERVALS

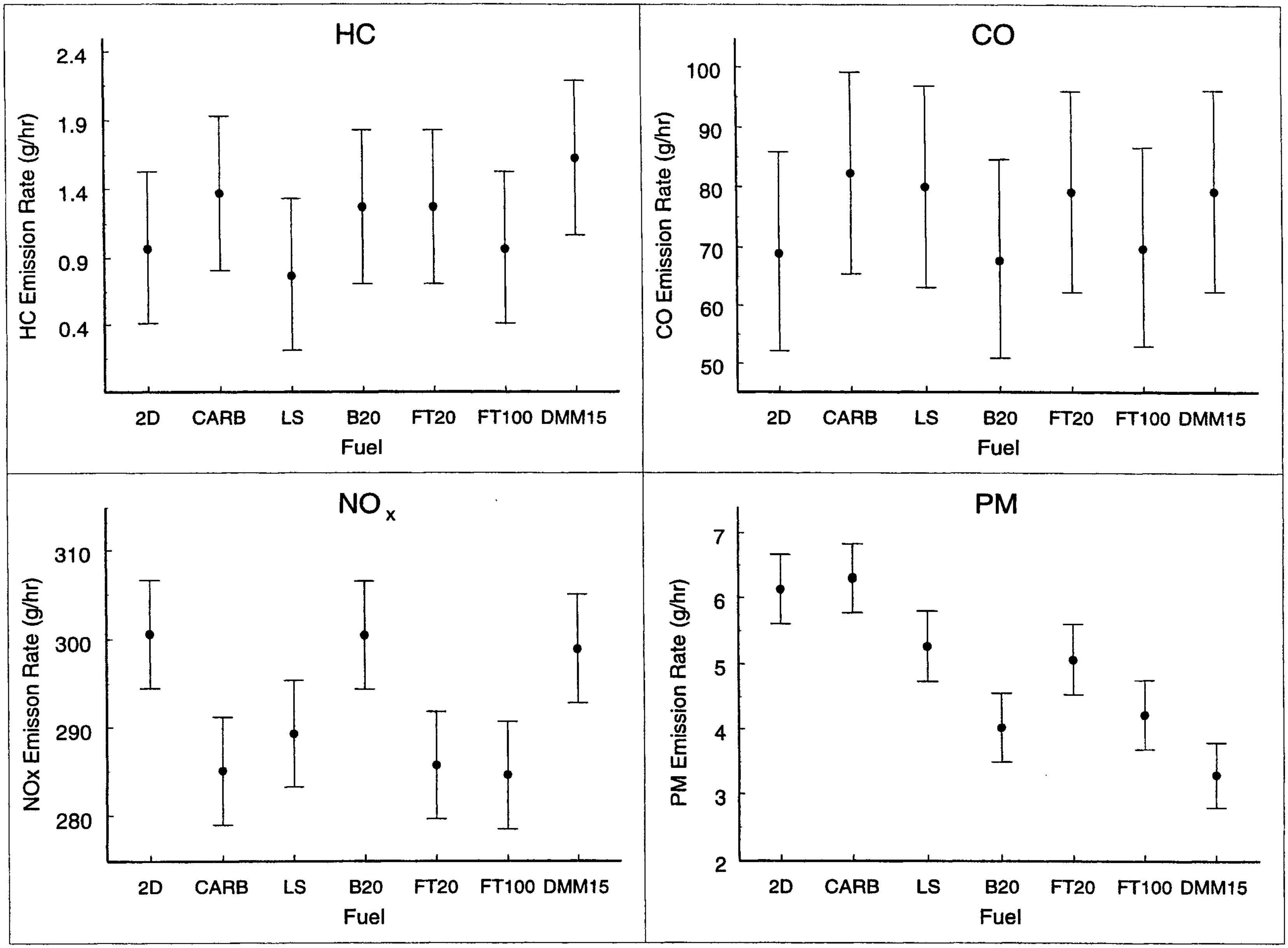

FIGURE D-8. MODE 8 EXHAUST EMISSION RATES, WITH 95 PERCENT CONFIDENCE INTERVALS

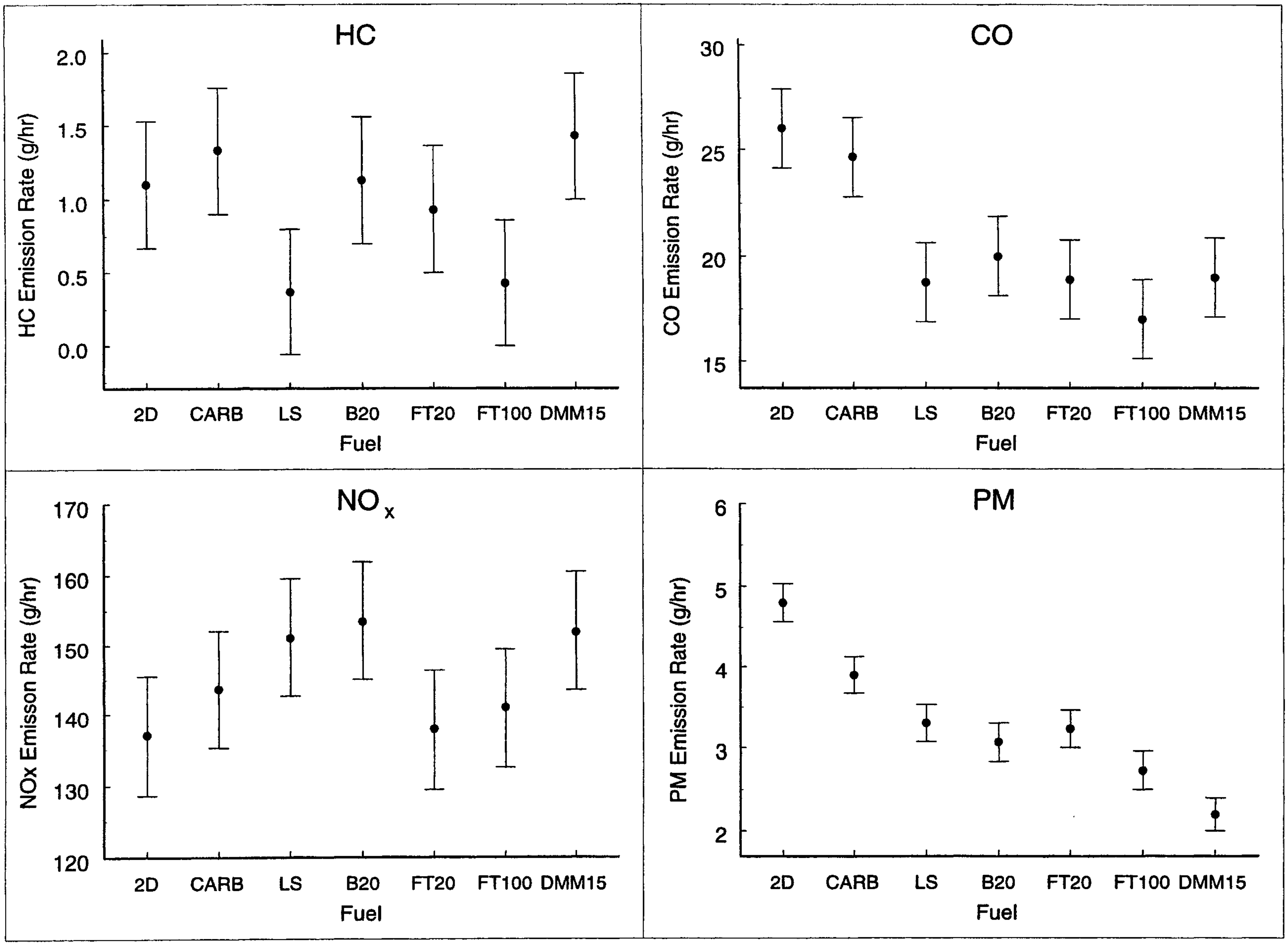

FIGURE D-9. MODE 9 EXHAUST EMISSION RATES, WITH 95 PERCENT CONFIDENCE INTERVALS

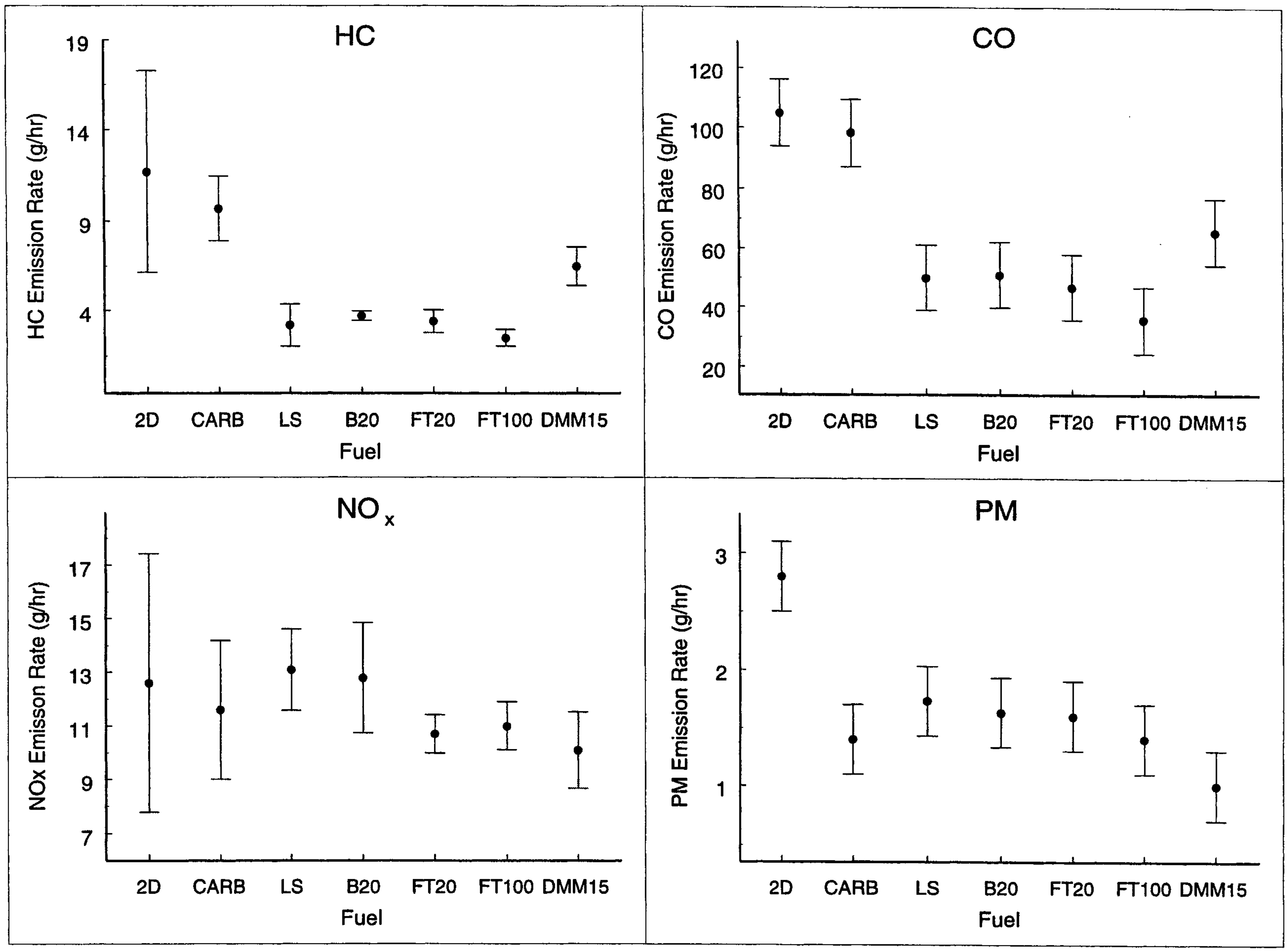

FIGURE D-10. MODE 10 EXHAUST EMISSION RATES, WITH 95 PERCENT CONFIDENCE INTERVALS

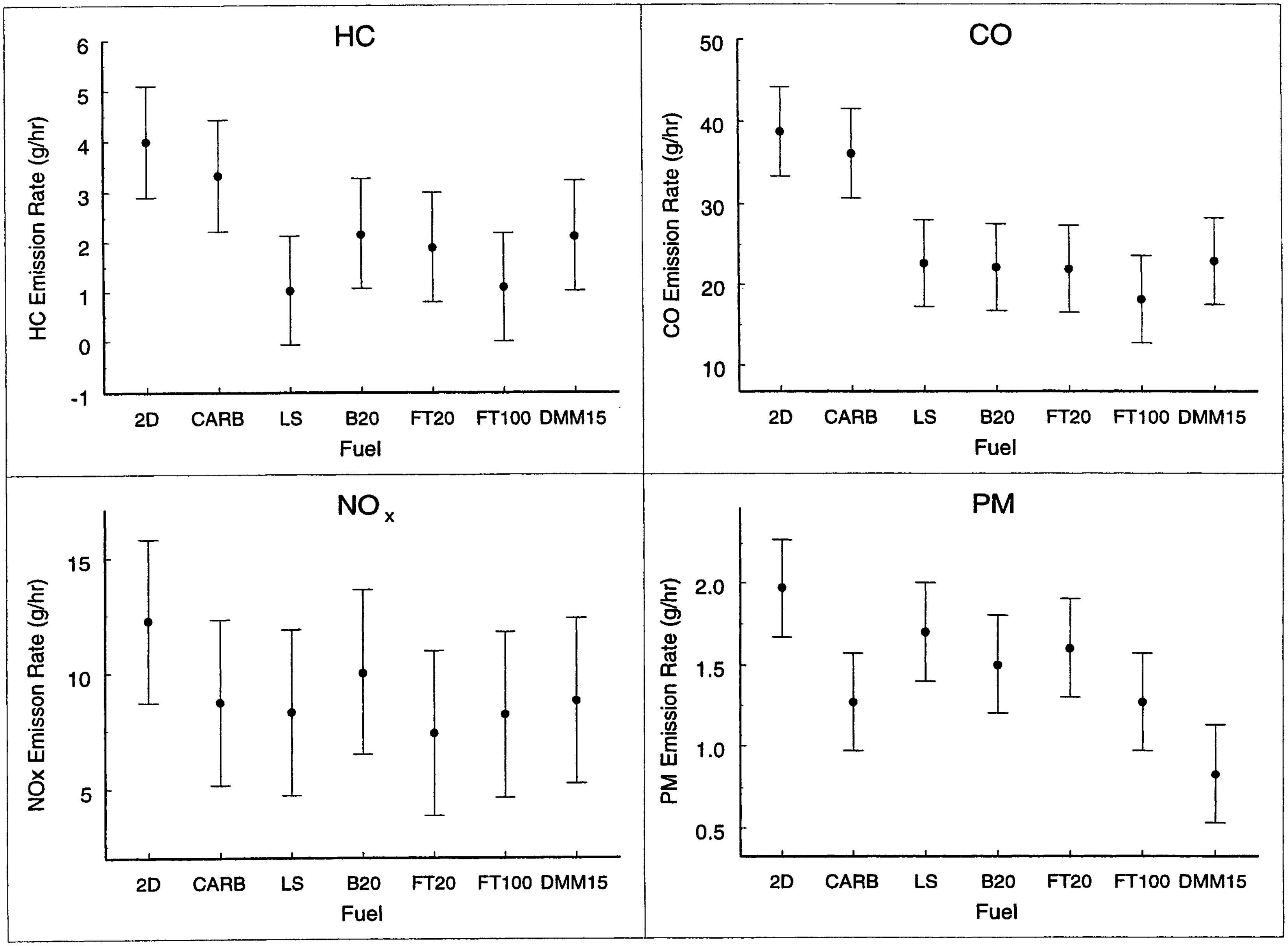

FIGURE D-11. MODE 11 EXHAUST EMISSION RATES, WITH 95 PERCENT CONFIDENCE INTERVALS

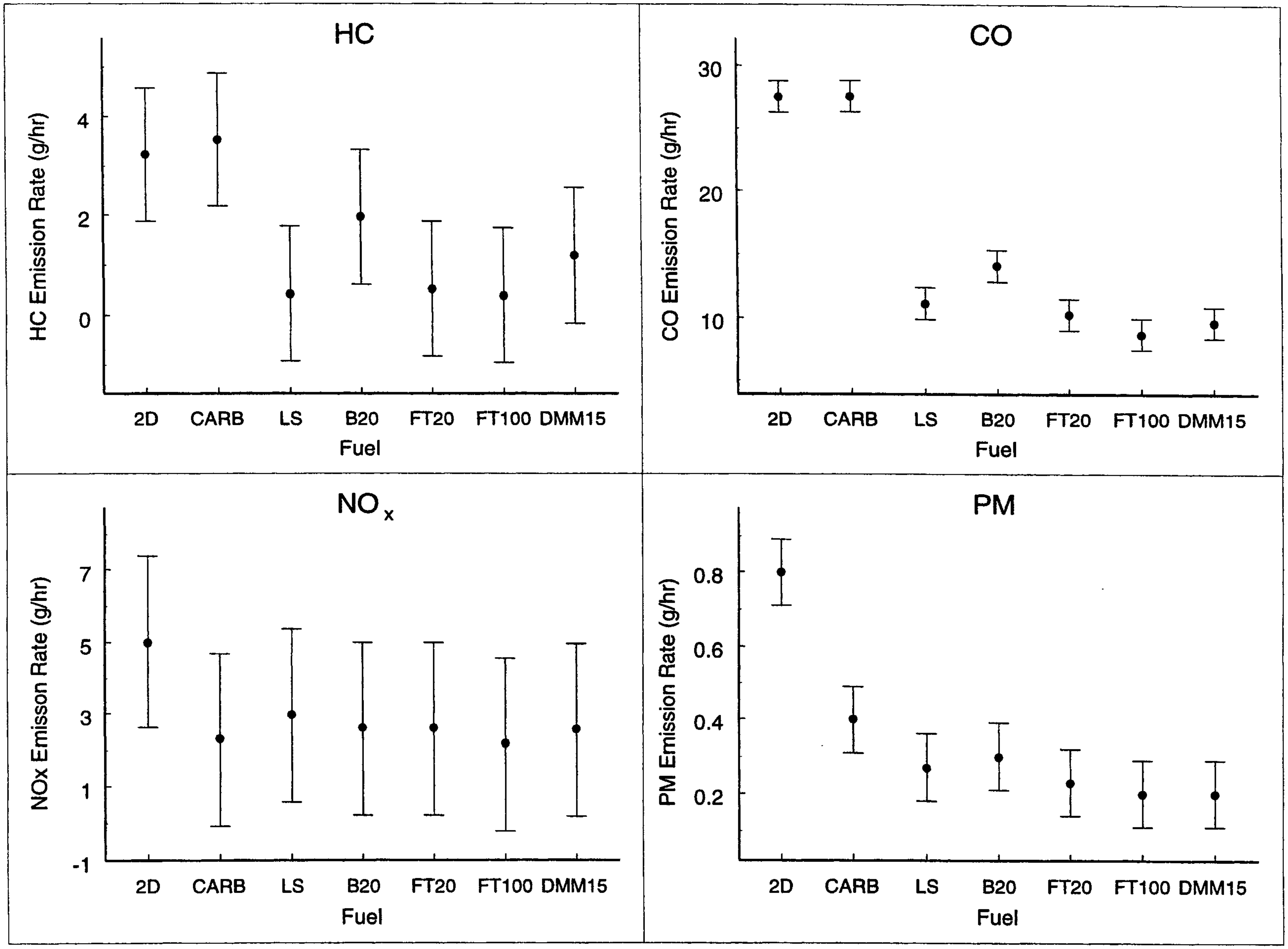

FIGURE D-12. MODE 12 EXHAUST EMISSION RATES, WITH 95 PERCENT CONFIDENCE INTERVALS

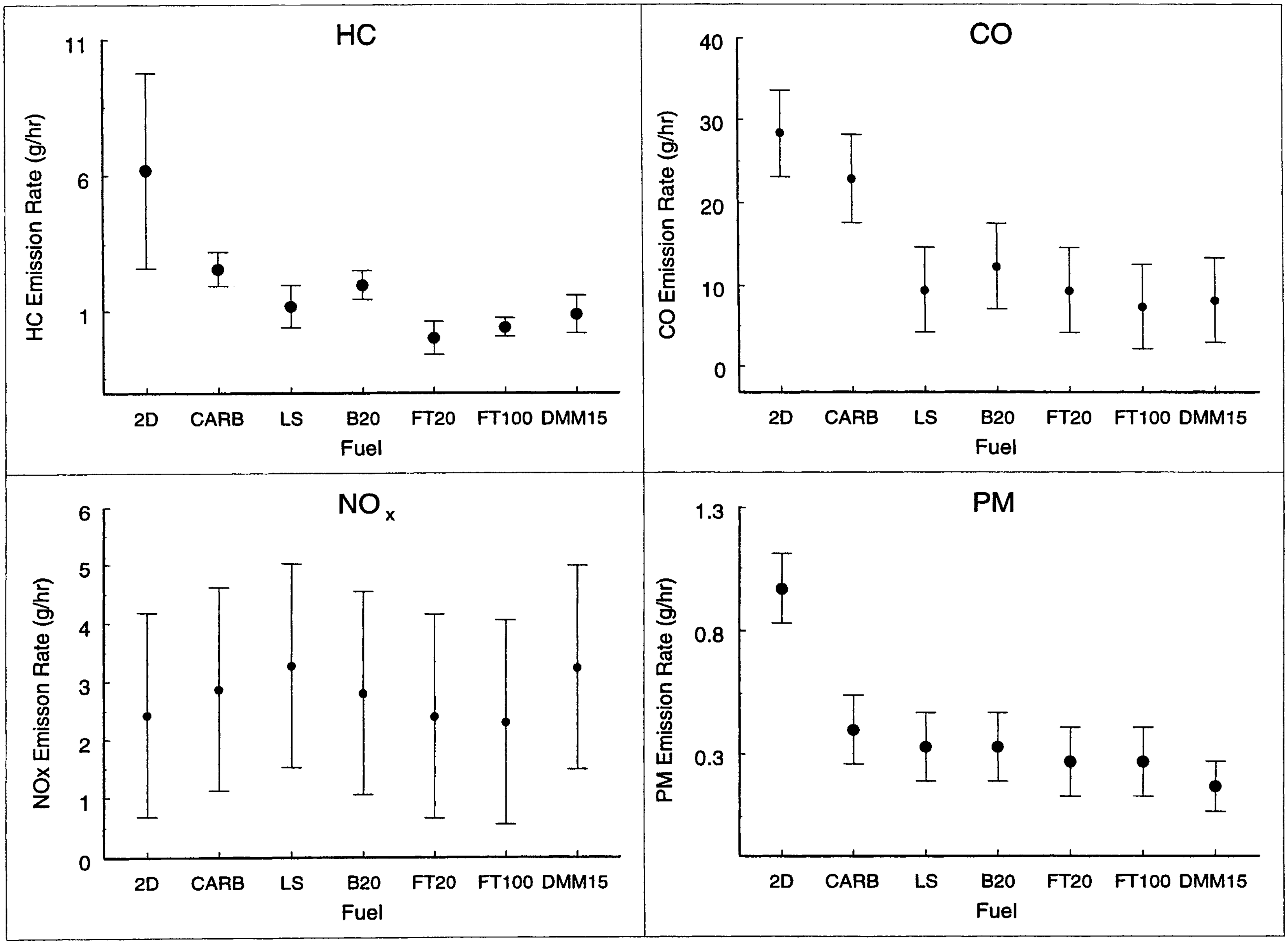

FIGURE D-13. MODE 13 EXHAUST EMISSION RATES, WITH 95 PERCENT CONFIDENCE INTERVALS

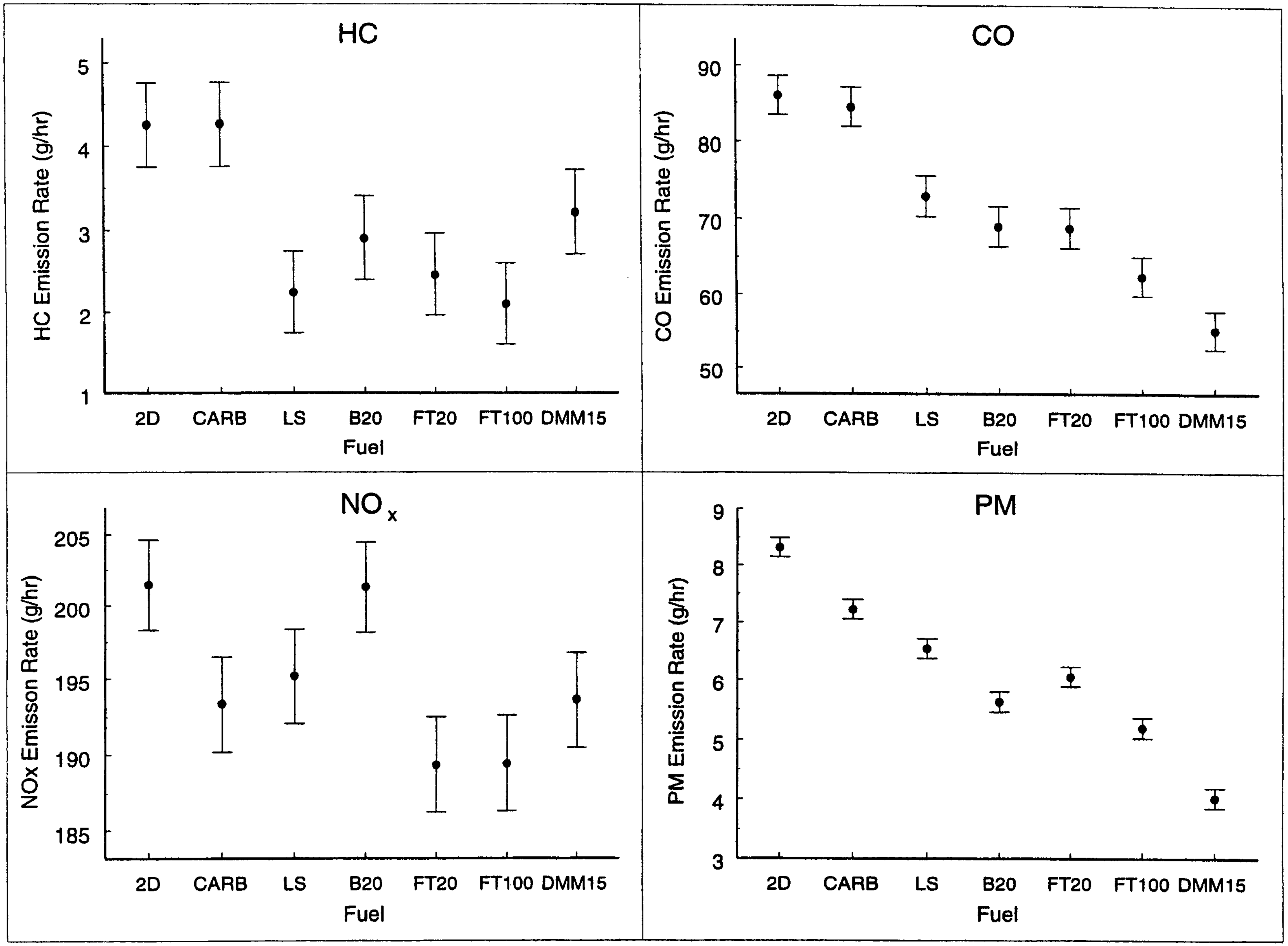

FIGURE D-14 COMPOSITE EXHAUST EMISSION RATES, WITH 95 PERCENT CONFIDENCE INTERVALS

APPENDIX E

SIZE-SEGREGATED PARTICULATE MASS EMISSION RESULT FOR INDIVIDUAL MODES

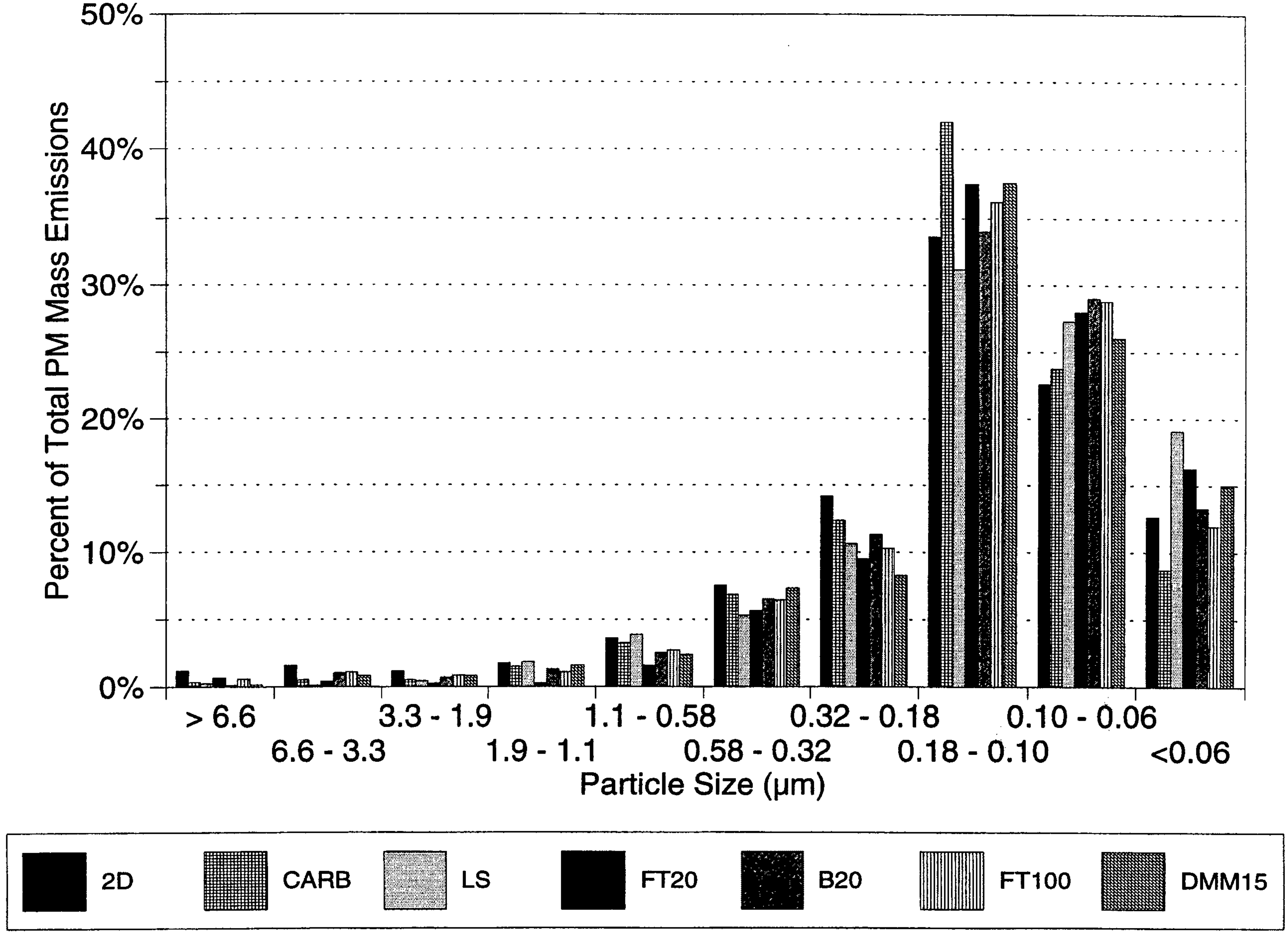

FIGURE E-1. MODE 1 SIZE SEGREGATED PARTICLE MASS

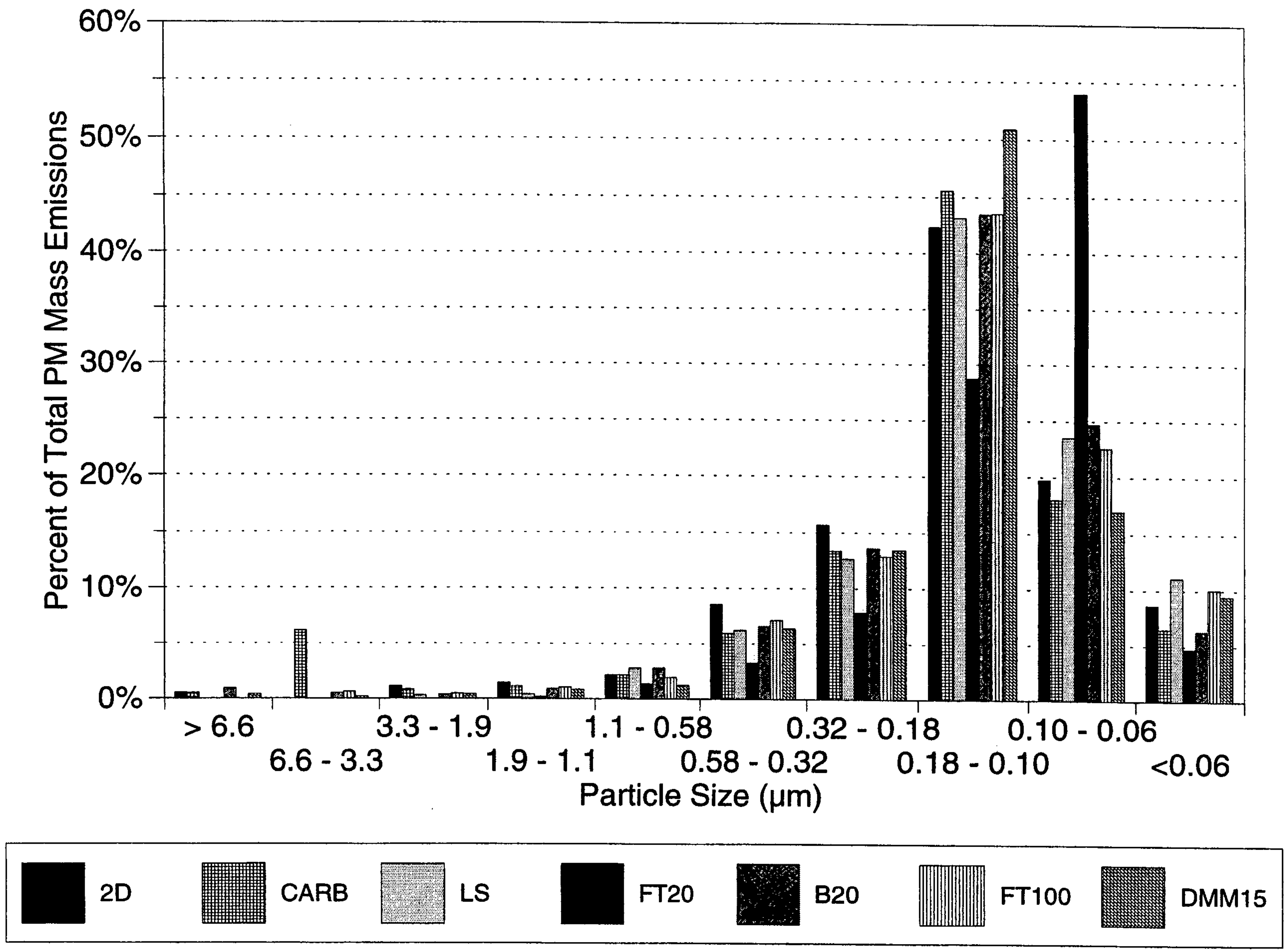

FIGURE E-2. MODE 2 SIZE SEGREGATED PARTICLE MASS

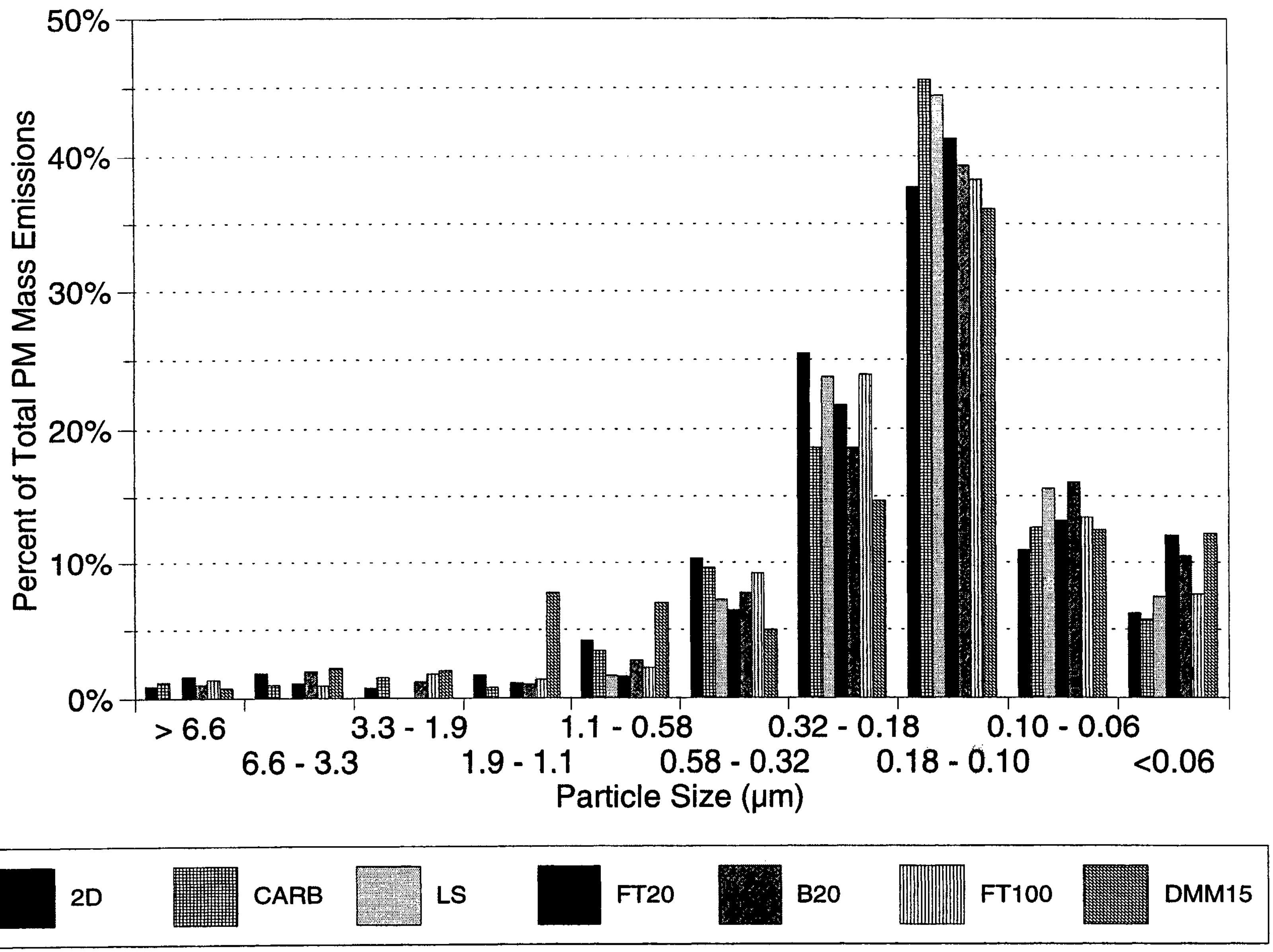

FIGURE E-3. MODE 3 SIZE SEGREGATED PARTICLE MASS

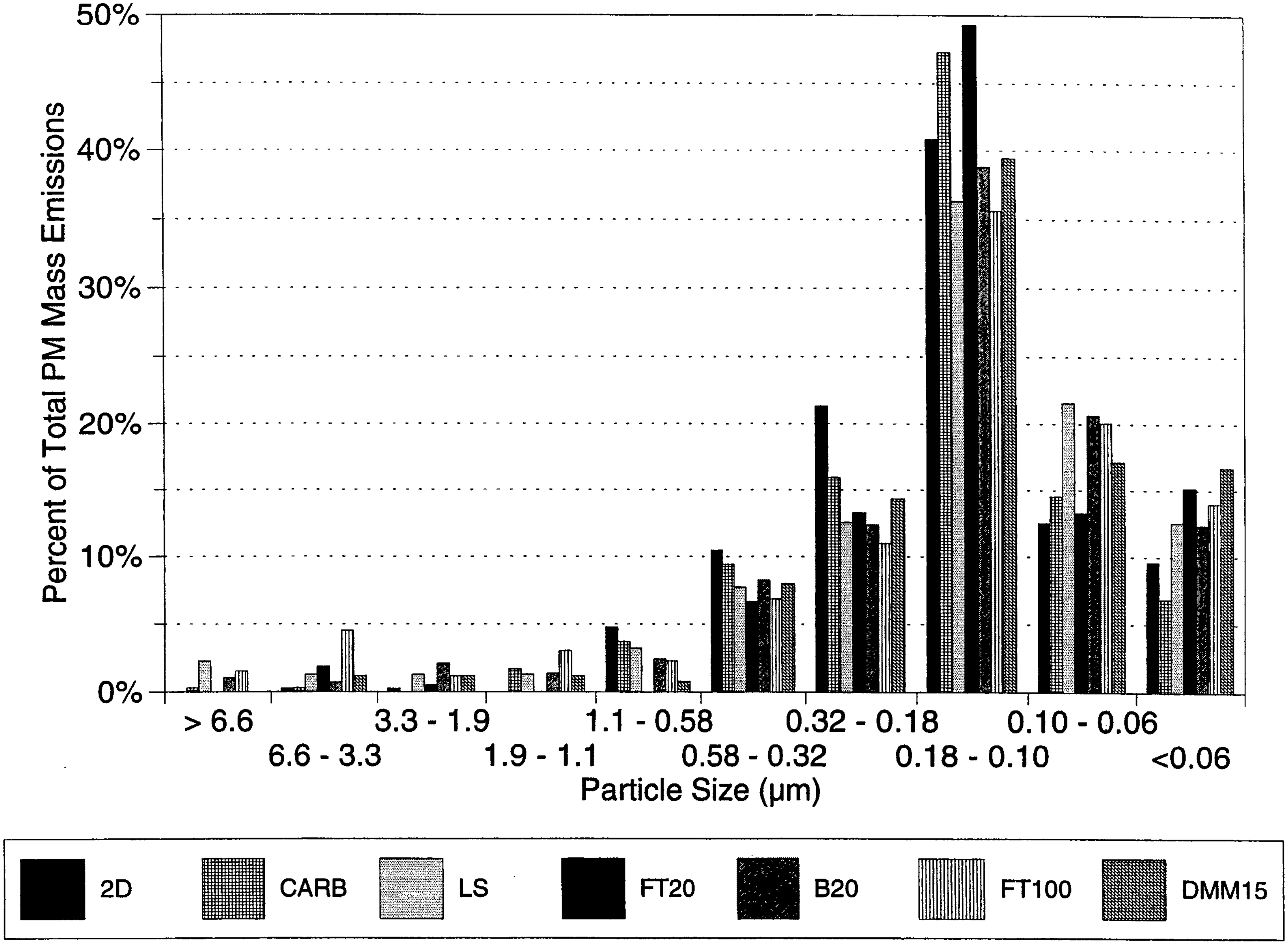

FIGURE E-4. MODE 4 SIZE SEGREGATED PARTICLE MASS

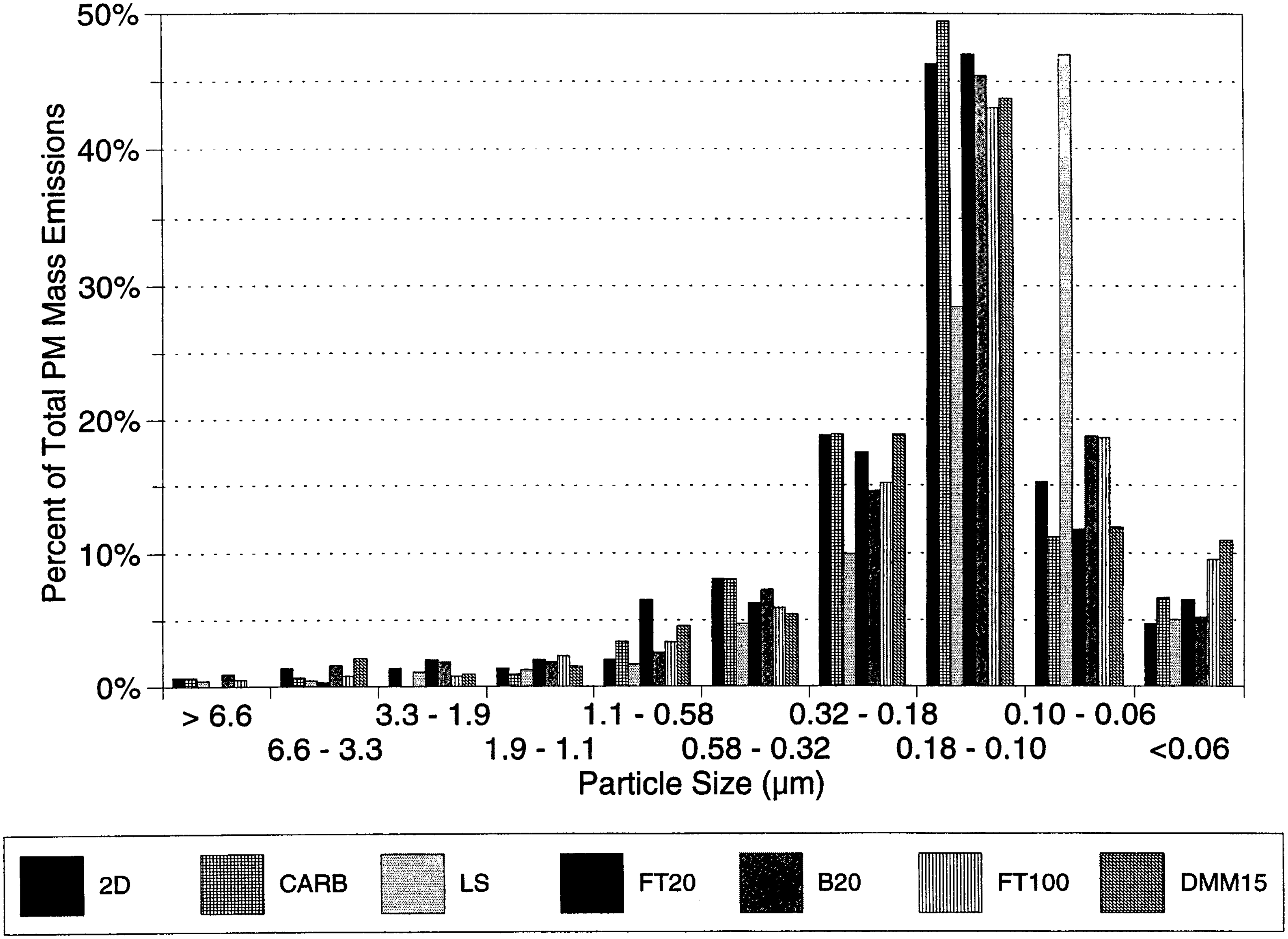

FIGURE E-5. MODE 5 SIZE SEGREGATED PARTICLE MASS

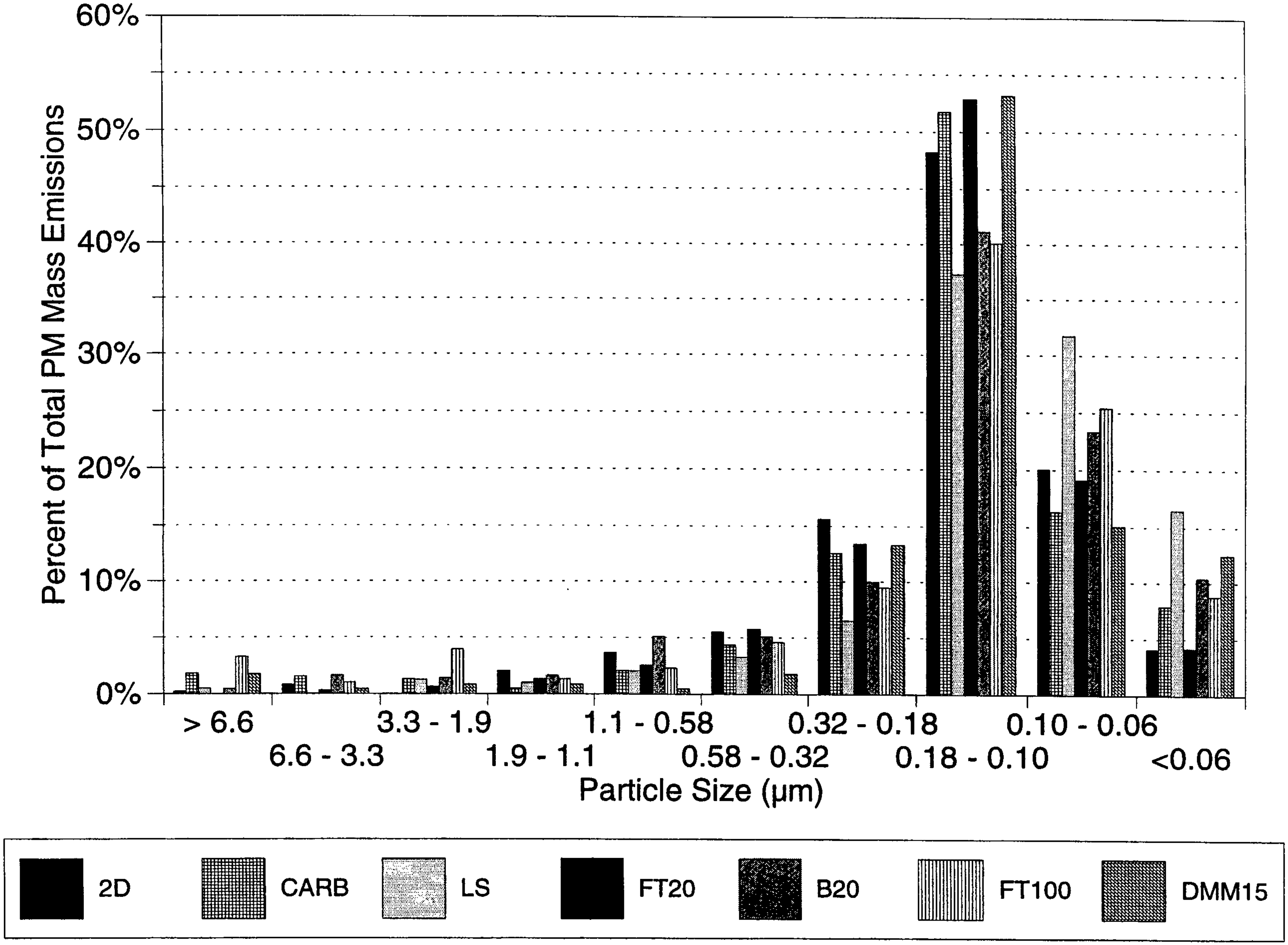

FIGURE E-6. MODE 6 SIZE SEGREGATED PARTICLE MASS

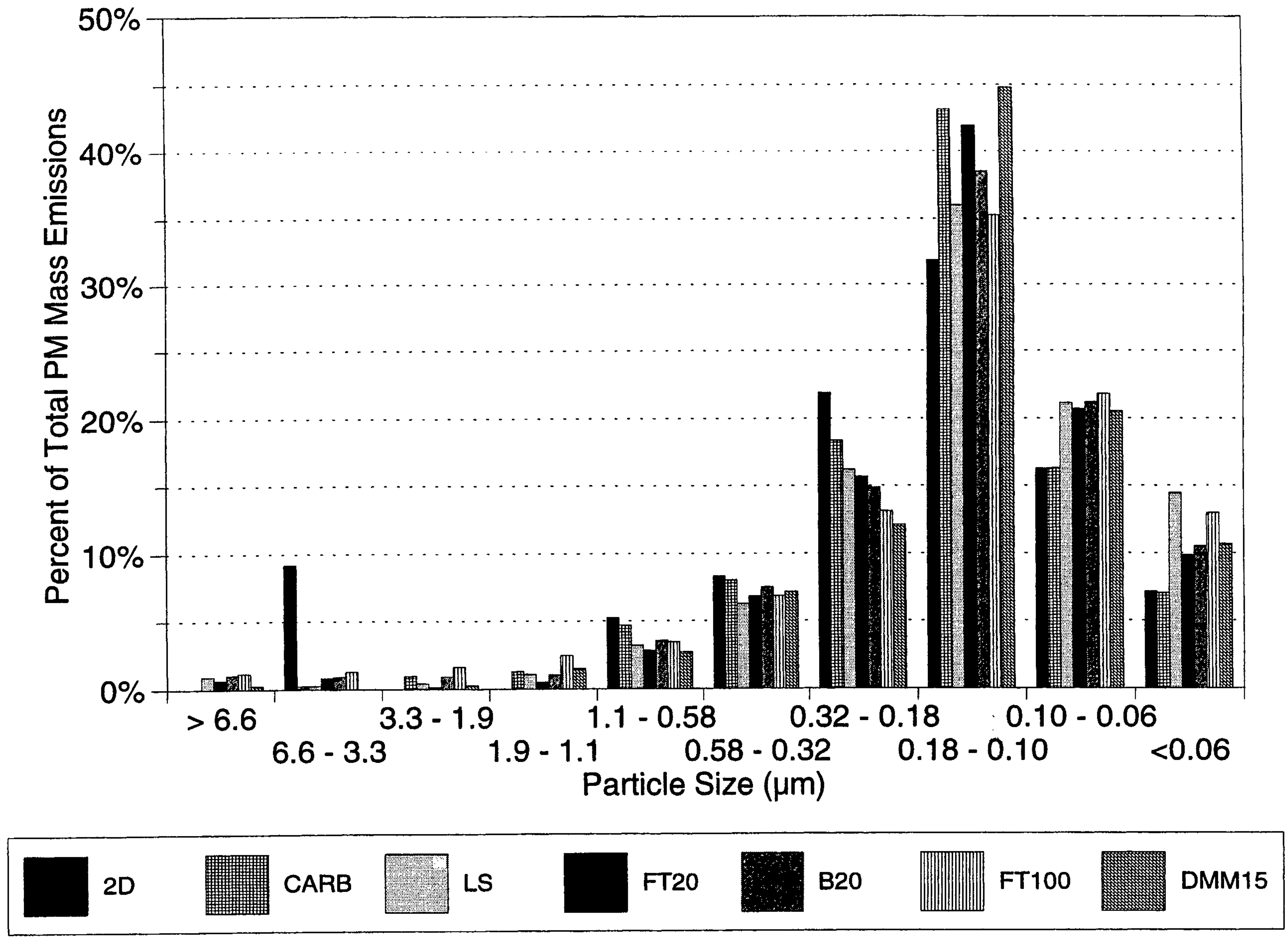

FIGURE E-7. MODE 7 SIZE SEGREGATED PARTICLE MASS

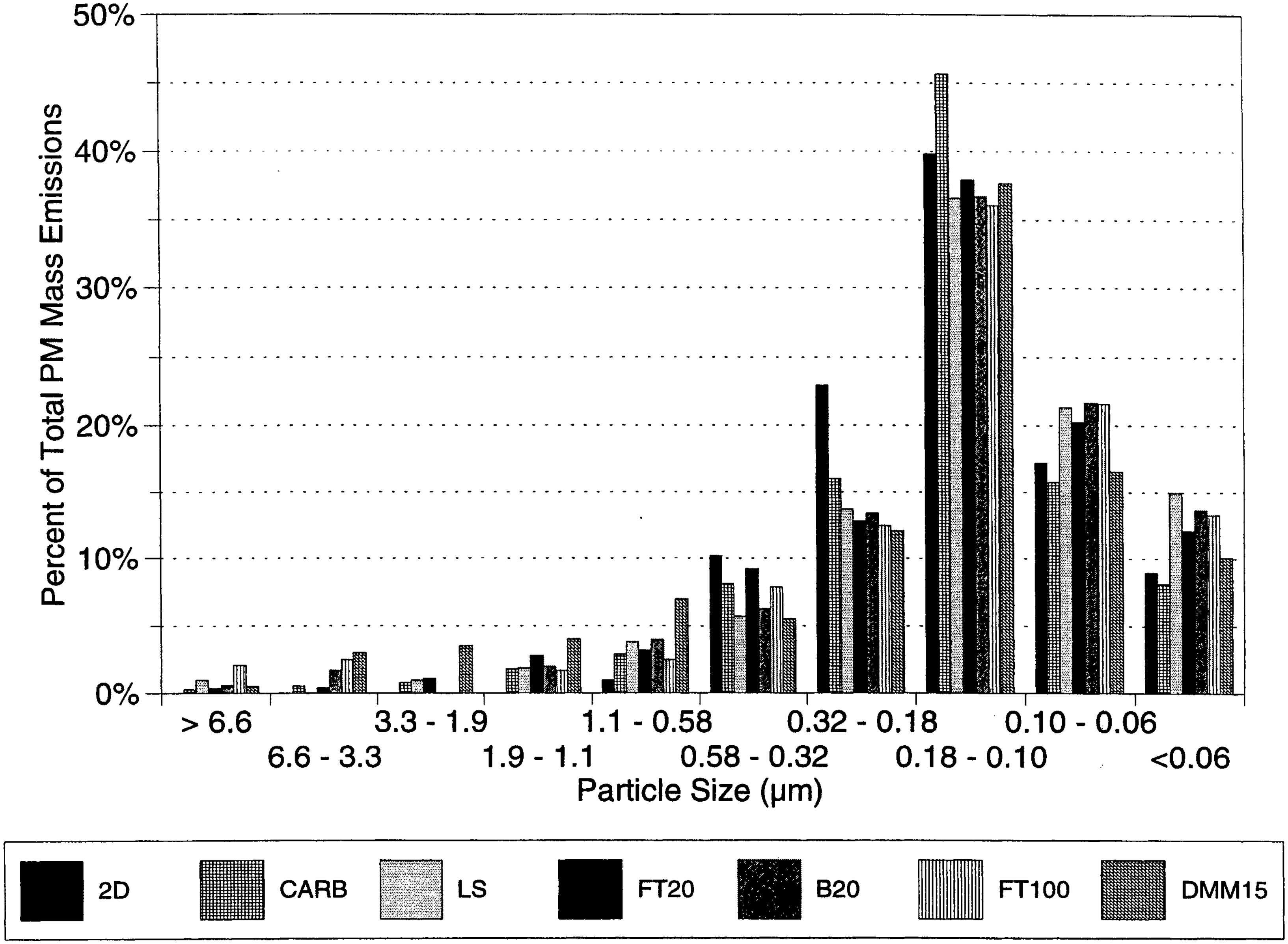

FIGURE E-8. MODE 8 SIZE SEGREGATED PARTICLE MASS

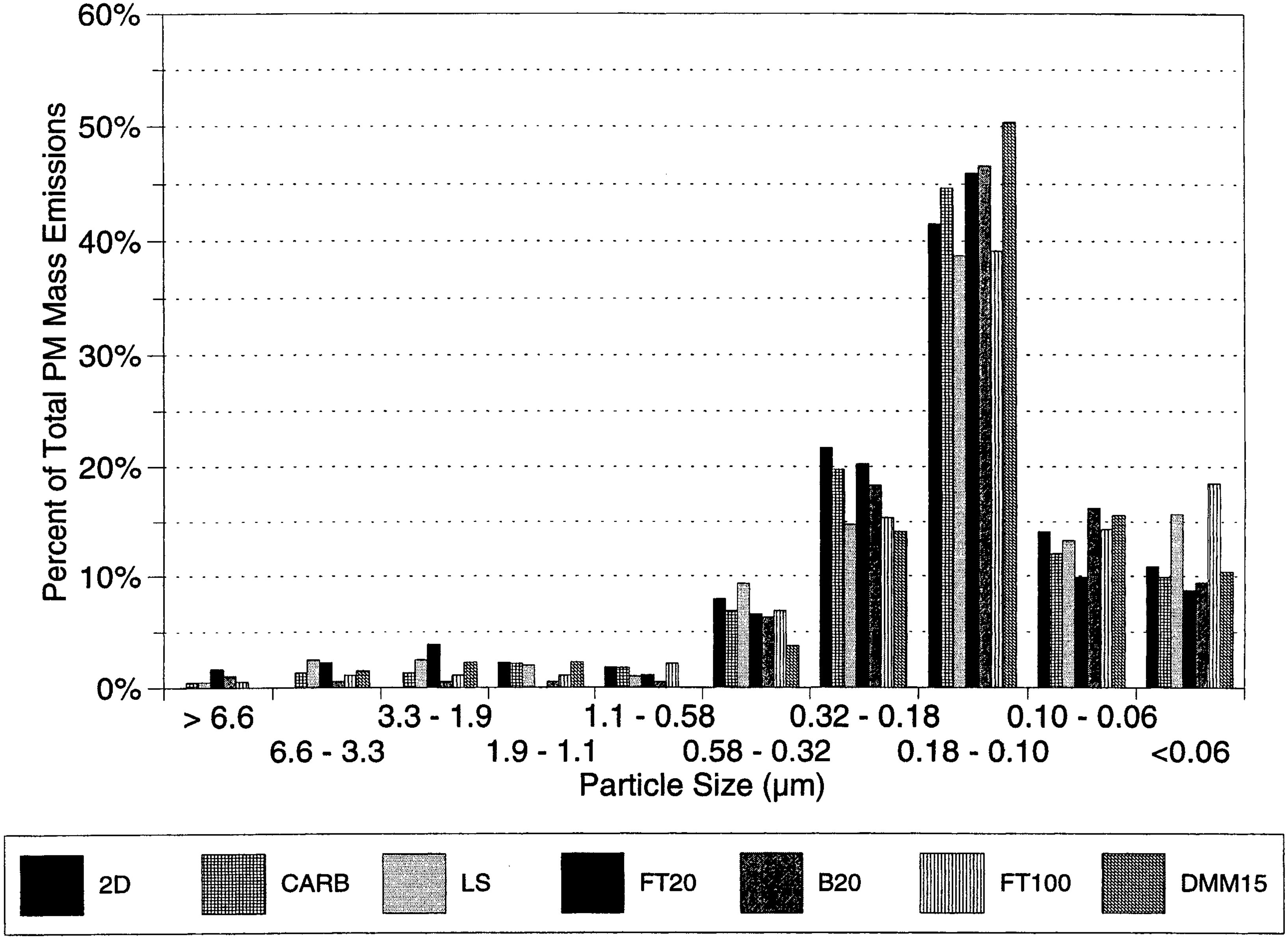

FIGURE E-9. MODE 9 SIZE SEGREGATED PARTICLE MASS

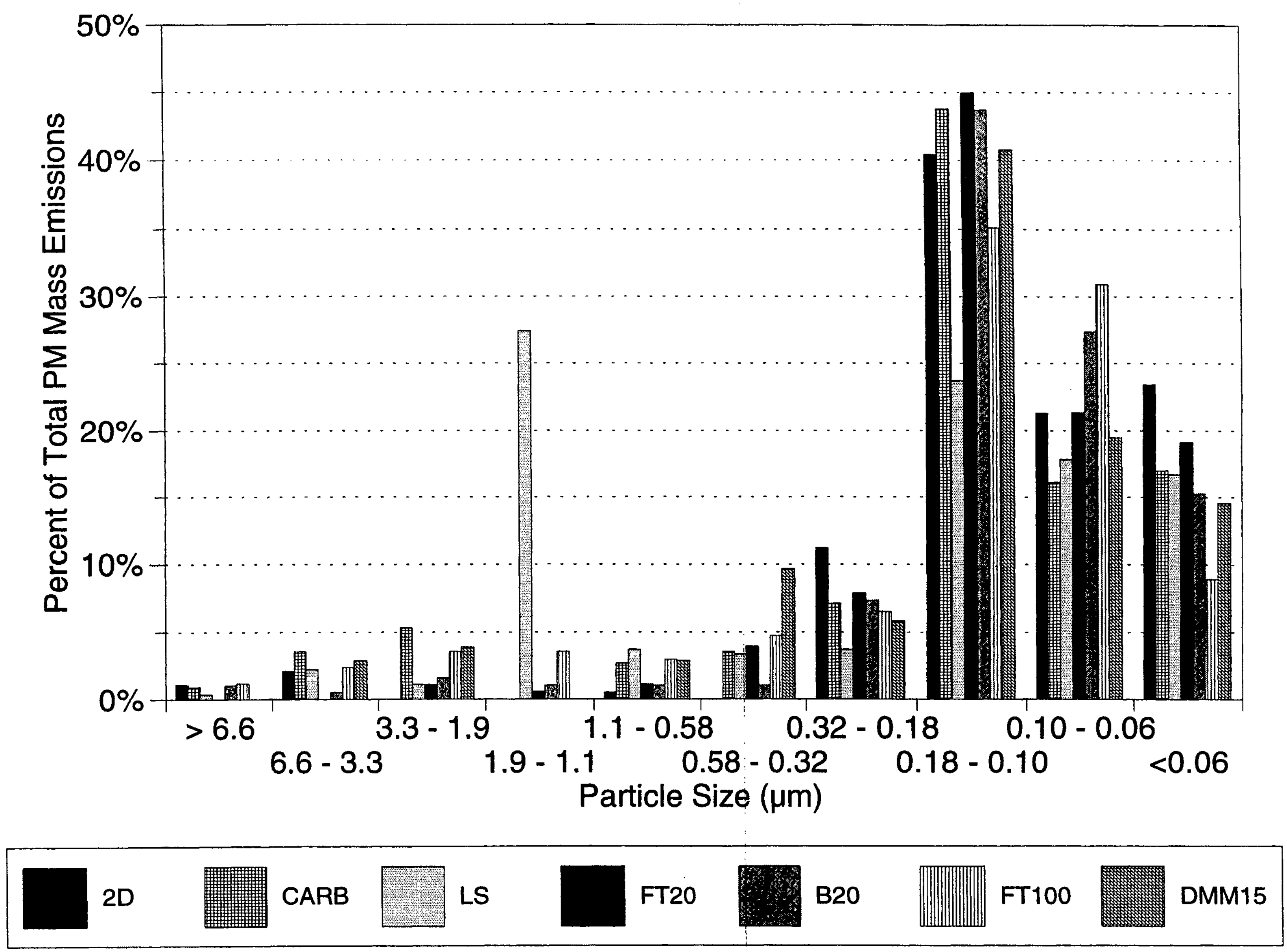

FIGURE E-10. MODE 10 SIZE SEGREGATED PARTICLE MASS

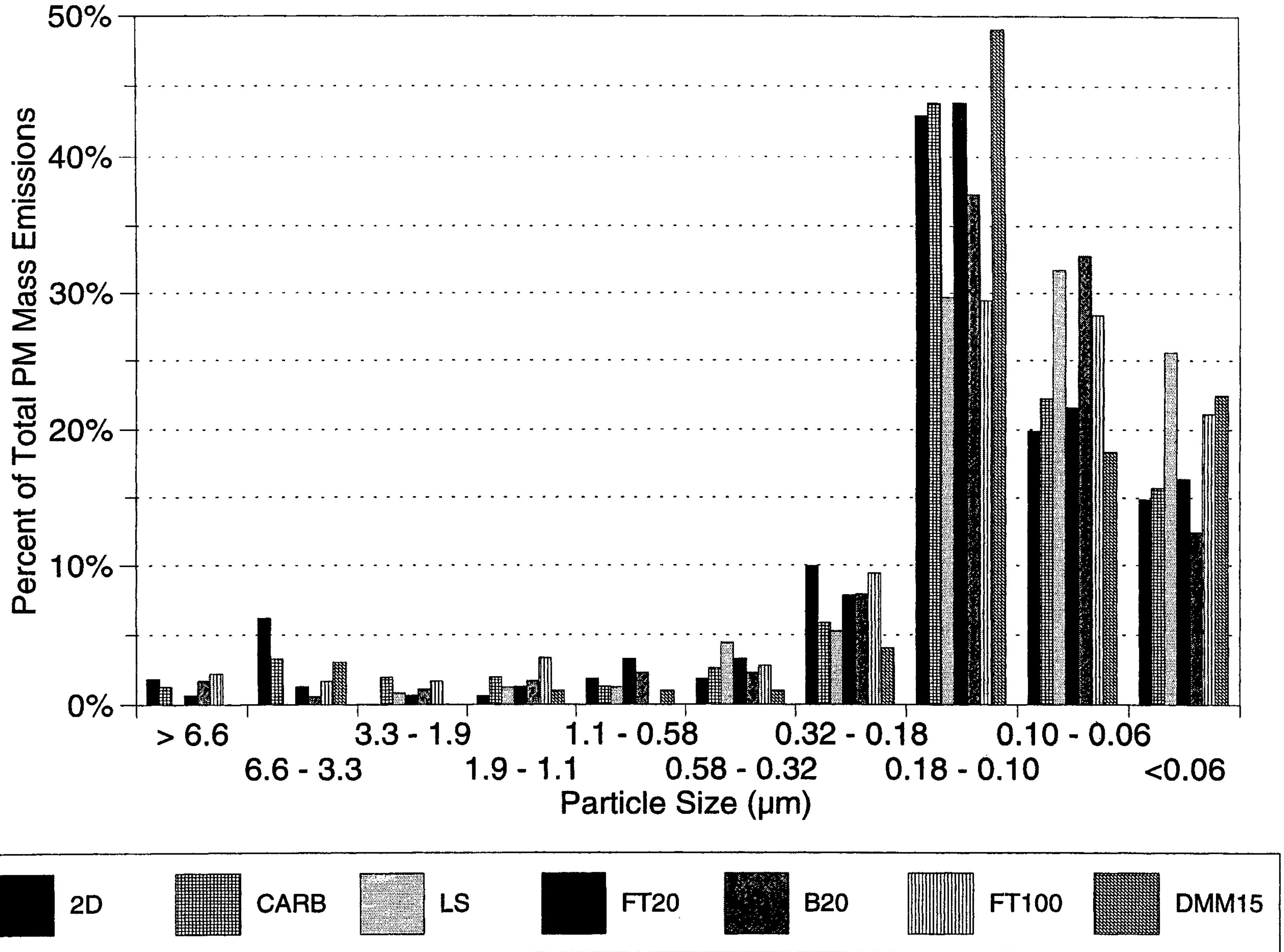

FIGURE E-11. MODE 11 SIZE SEGREGATED PARTICLE MASS

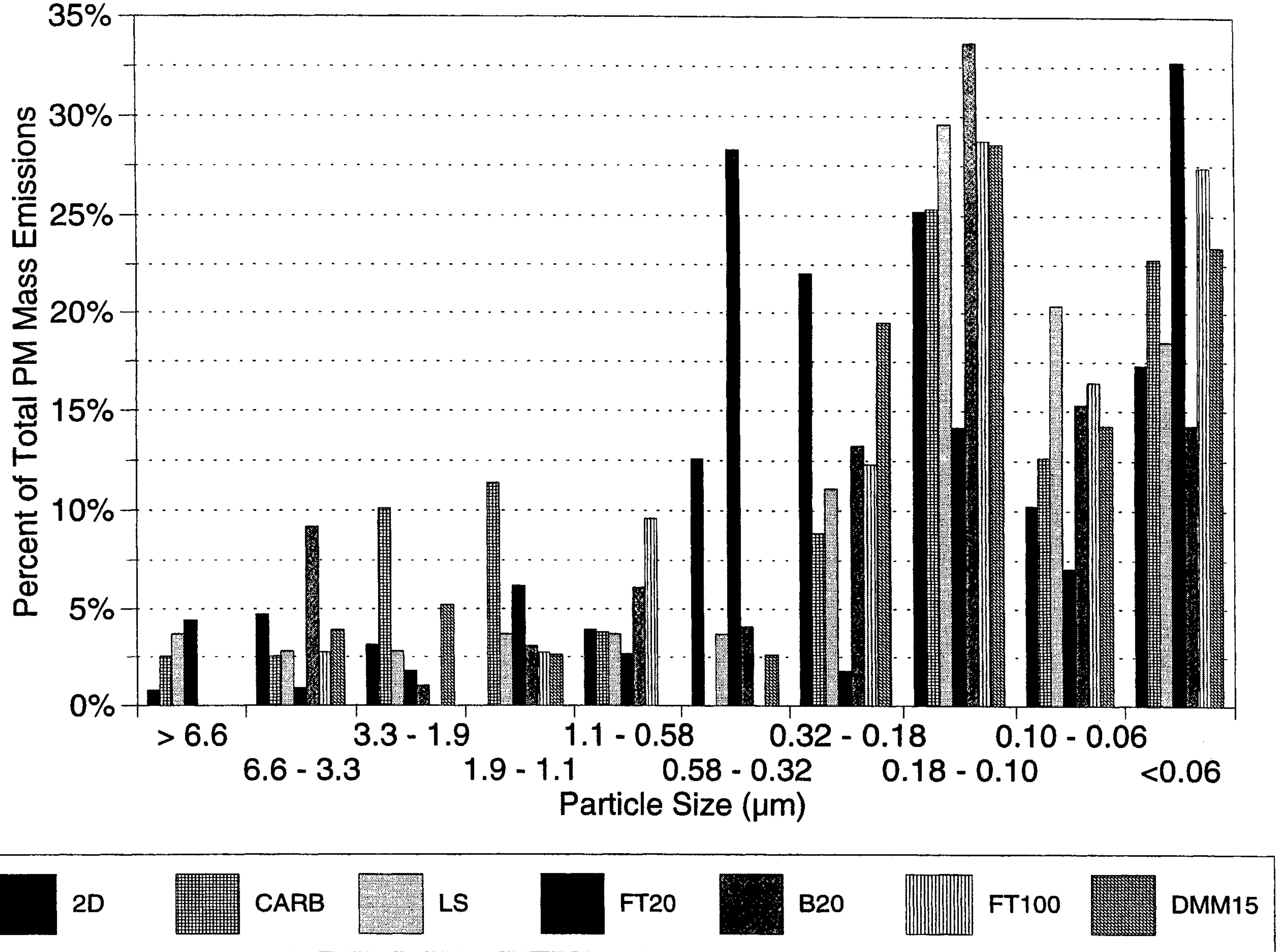

FIGURE E-12. MODE 12 SIZE SEGREGATED PARTICLE MASS

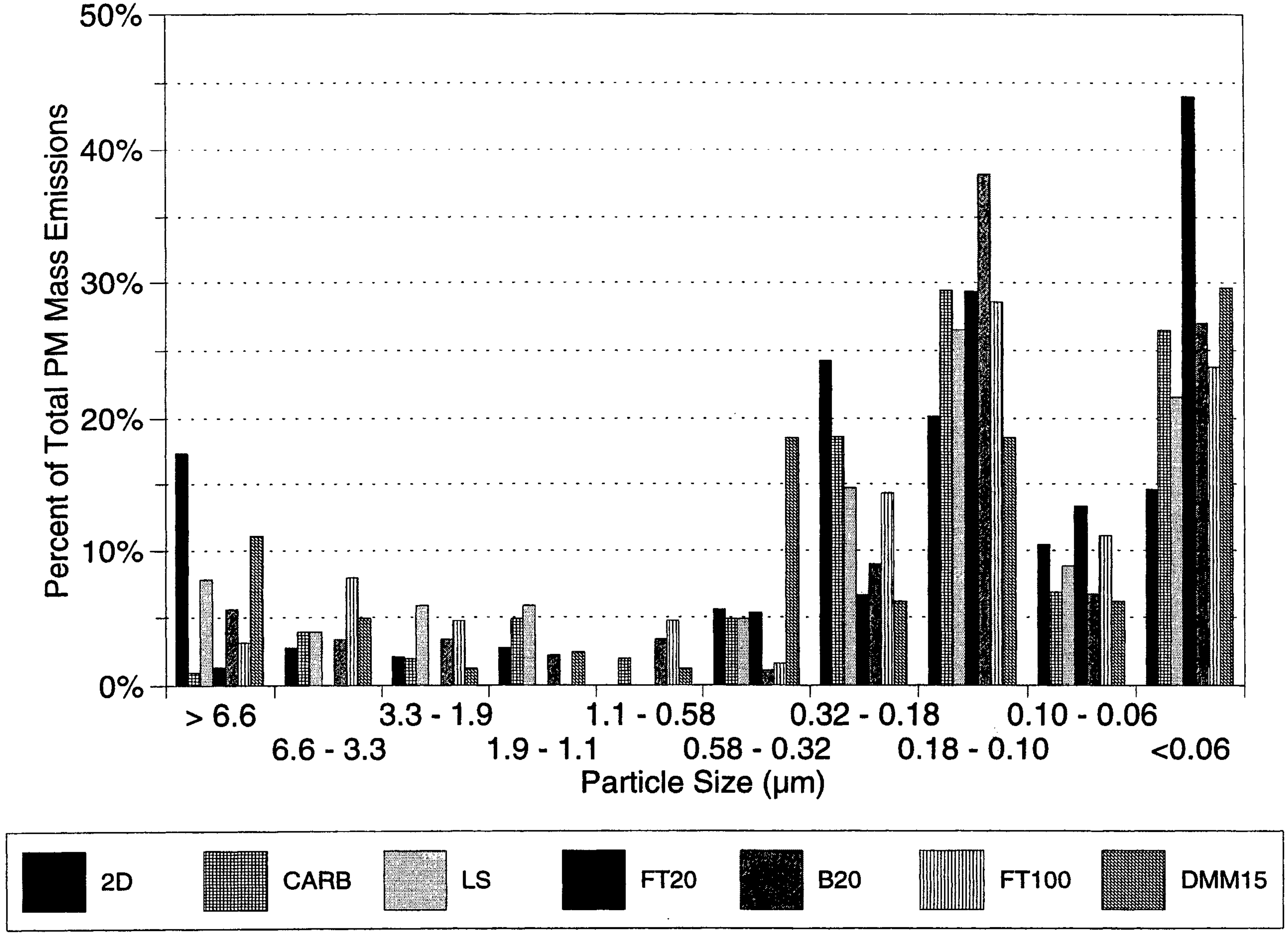

FIGURE E-13. MODE 13 SIZE SEGREGATED PARTICLE MASS

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